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"Time for Change"

ABSTRACT BOOK

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AIGeo – Associazione Italiana di Geografia Fisica e Geomorfologia

ENEA – Ente per le Nuove Tecnologie, l'Energia e l'Ambiente

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AIGA – Associazione Italiana di Geologia Applicata e Ambientale

OGS

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1. Peking University

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Mr. Zuorui Liu[1], Ms. Rheia Edgar-Nemec [2], Dr. Amy Prendergast [3], Prof. Russell Drysdale [4], Dr. Orr Comay [5], Dr. Yoav Motro [6], Ms. Michal Zaitzove-Raz [5], Dr. Sarah Pederzani [7], Prof. Miriam Belmaker [8]

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Ms. Robyn R. Messer [1], Dr. Orr Comay [2], Dr. Yoav Motro [3], Dr. Tom Curtis [4], Ms. Michal Zaitzove-Raz [2], Prof. Miriam Belmaker[5]

1. Department of Anthropology and Sociology, The University of Tulsa, 2. Steinhardt Museum of Natural History, Tel Aviv, Israel, 3. Israel Ministry of Agriculture, Jerusalem, Israel, 4. Oklahoma State University - Center for Health Sciences, 5. University of Tulsa

The palaeoenvironmental context for early Pleistocene Homo dispersals in the Levant from multi proxy analyses of gastropod shells, Ubeidiya, Israel **1968**

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Macrofaunal stable isotopes from 'Ubeidiya, Israel, shed light on environmental setting of an early presence of Homo in the Levant **1969**

Dr. Sarah Pederzani[1], Mr. Zuorui Liu [2], Dr. Amy Prendergast [3], Prof. Russell Drysdale [4], Prof. Miriam Belmaker [5]

1. Archaeological Micromorphology and Biomarkers Laboratory (AMBI Lab), Instituto Universitario de Bio-Orgánica "Antonio González", University of La Laguna, San Cristóbal de La Laguna, Tenerife, Spain, 2. School of Geography, University of Melbourne, Melbourne, 3. School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Victoria, Australia, 4. University of Melbourne, 5. University of Tulsa

Geomorphology and lithology of Dakhla yardangs **1970**

Dr. Driss Chahid[1], Prof. Aicha Oujaa [2], Prof. Larbi Boudad [3], Dr. Arnaud Lenoble [4]

1. Department of Geology, Faculty of Sciences, University Mohammed V, 2. National Institute of Sciences of Archeology and Heritage RABAT, 3. Mohammed V University, Faculty of Sciences, Rabat, Morocco, 4. PACEA - UMR 5199, CNRS, University of Bordeaux

Lipid biomarkers at the Late Pleistocene open-air loess site Ollersdorf-Heidenberg (Austria) 1977

Dr. Marjolein Bosch[1], Dr. Margarita Jambrina-Enríquez [2], Dr. Stéphane Pirson [3], Dr. Freddy Damblon [4], Mr. William Murphree [5], Dr. Carolina Mallol [6], Dr. Walpurga Antl-Weiser [7], Prof. Philip Nigst [8]

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Residue analysis as a tool for reconstructing funerary and agricultural practices and vessel use history at the dawn of Egyptian history 1978

Dr. Amber Hood[1], Dr. Julie Dunne [2], Prof. E. Christiana Köhler [3], Dr. Friederike Junge [3]

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Dietary lipid residues and insights for land use and vegetation change 1979

Dr. Emma Loftus[1], Prof. Simon Hammann [2]

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Lipid biomarkers and micromorphology of a Middle Paleolithic combustion structure from Axlor cave (northern Spain) 1980

Dr. Margarita Jambrina-Enríquez[1], Dr. Antonio V. Herrera-Herrera [2], Dr. Carolina Mallol [2], Dr. Jesús González-Urquijo [3], Dr. Talía Lazuen [3]

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Neolithic Human Diet Based on Studies of Coprolites from the Swifterbant Culture Sites, the Netherlands 1981

Dr. Marjolein van der Linden[1], Dr. Lucy Kubiak-Martens [1], Dr. Karen Hardy [2], Dr. Helen Mackay [3], Dr. Dominique Ngan-Tillard [4], Dr. Jorn Zeiler [5], Dr. Lisa-Marie Shillito [6]

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Degradation patterns by thermoalteration of lipid biomarkers: an experimental case for tracking Neanderthal behaviour. **1982**

Ms. Sandra Gómez-Soler[1], Dr. Natalia Égüez-Gordon [2], Dr. Antonio V. Herrera-Herrera [3], Dr. Carolina Mallol [2], Dr. Belén Márquez [4], Dr. César Laplana [4], Ms. Lucía Villaescusa [1], Dr. M. Ángeles Galindo-Pellicena [5], Dr. Rosa Huguet [6], Prof. Juan Luis Arsuaga [7], Prof. Alfredo Pérez-González [8], Dr. Enrique Baquedano [9]

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Domestication, diet and defecation: an integrated biomolecular and micro-contextual approach to archaeological faecal matter in sedentarising societies **1983**

Dr. Aroa Garcia-Suarez[1], Dr. Marta Portillo [1]

1. *Spanish National Research Council*

Sensitive identification and quantification of food biomarkers in roman age ceramic pottery **1984**

Ms. Ane Gorostizu-Orkaiztegi[1], Ms. Paula Saez-Aduna [1], Ms. Amaia Alday-Izaguirre [1], Ms. Ainhoa Elejaga-Jimeno [1], Dr. María Carmen Sampedro [1], Dr. Alicia Sánchez-Ortega [1], Dr. Mattin Aiestaran [2], Dr. Jose Antonio Múgica [3], Dr. Asier Vallejo [1]

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Recent environmental changes around the cross-border channel of ''Gbaga" **1985**

Prof. Ibouraïma Yabi[1], Mr. Bernard Gbadessi [1], Dr. Innocent Akpaka [1]

1. *University of Abomey Calavi*

Socio-economic and environmental impacts of the spatial evolution of temperature and dissolved oxygen in the fisheries of Lake Nokoue (southern Benin). **1986**

Dr. florentin totin[1], Prof. Ernest AMOUSSOU [2], Prof. Henri Sourou TOTIN VODOUNON [2]

1. *Laboratoire Pierre PAGNEY. Climat, Eau, Écosystème et Développement (LACEEDE),,* ***2.*** *Department of Geography, University of Parakou*

Drivers of the evolution and amplitude of African Humid Periods **1987**

Dr. Laurie Menviel[1], Dr. Aline Govin [2], Mr. Arthur Avenas [3], Prof. Katrin Meissner [4], Dr. Katharine Grant [5], Prof. Chronis Tzedakis [6]

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Finding Suitable Grounds: Early crop cultivation in the lagoonal-deltaic landscapes of the Netherlands 1988

Ms. Elena Familetto[1], Prof. Hans Huisman [2], Dr. Kim M. Cohen [1], Dr. Wim Hoek [1], Prof. Esther Stouthamer [1]

1. Dept. of Physical Geography, Faculty of Geosciences, Utrecht University, 2. Groningen Instiitute of Archaeology

The micromorphology of iceberg-keel scoured diamictons from the Bellingshausen and Amundsen Seas: An approach to improving reconstructions of West Antarctic Ice Sheet extent 1989

Dr. Lorna Linch[1], Dr. Claus-Dieter Hillenbrand [2], Dr. James Smith [2], Prof. Jaap van der Meer [3], Dr. Rob Larter [2], Dr. Alastair Graham [4], Dr. Benedict Reinardy [5]

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Sand, hearths, lithics, and a bit of bioturbation: Micromorphological investigations at Umhlatuzana rock-shelter, South Africa 1990

Ms. Irini Sifogeorgaki[1], Mr. Hans Huisman [2], Dr. Panagiotis Karkanas [3], Ms. Viola Schmid [4], Mr. Gerrit Dusseldorp [1]

1. Faculty of Archaeology, Leiden University, Einsteinweg 2, 2333, CC, the Netherlands, 2. Groningen Instiitute of Archaeology, 3. M.H. Wiener Laboratory for Archaeological Science, American School of Classical Studies at Athens, Athens, Greece, 4. Austrian Archaeological Institute, Austrian Academy of Sciences, Hollandstrasse 11-13, 1020 Vienna,

Compositional, micromorphological and stratigraphic characterization of Holocene Tiber floodplain deposits (Rome, Italy) 1991

Dr. Daniel Tentori[1], Dr. Marco Mancini [1], Prof. Salvatore Milli [2], Dr. Francesco Stigliano [1], Dr. Massimiliano Moscatelli [1]

1. Istituto di Geologia Ambientale e Geoingegneria (IGAG), Consiglio Nazionale delle Ricerche, Via Salaria km 29,300, Monterotondo Stazione, 00015 Rome, Italy, 2. Department of Earth Sciences, Sapienza University of Rome

Investigating duricrust diagenesis through high-resolution petrographic and geochemical methods 1992

Dr. Shlomy Vainer[1], Prof. Eric Verrecchia [2]

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Morphological analysis of mineral grains from different sedimentary environments using automated static image analysis 1993

Ms. Fruzsina Gresina[1], Ms. Beáta Farkas [2], Dr. Szabolcs Ákos Fábián [2], Dr. Zoltán Szalai [1], Dr. György Varga [3]

1. Geographical Institute, Research Centre for Astronomy and Earth Sciences, Budapest, Hungary; Institute of Geography and Earth Sciences, Eötvös Loránd University, Budapest, Hungary, 2. Department of Physical and Environmental Geography,Institute of Geography and Earth Sciences, University of Pécs, Pécs, Hungary, 3. Geographical Institute, Research Centre for Astronomy and Earth Sciences, Budapest, Hungary; Department of Meteorology, Eötvös Loránd University, Budapest, Hungary

Micromorphological insights within the Middle Pleistocene-Holocene cave sediment record of Grotta Romanelli, Italy 1994

Dr. Guido Stefano Mariani[1], Prof. Pierluigi Pieruccini [1], Dr. Luca Forti [2], Dr. Ilaria Mazzini [3], Dr. Beniamino Mecozzi [4], Prof. Raffaele Sardella [4]

1. Dipartimento di Scienze della Terra, Università degli Studi di Torino, Torino, Italy, 2. Dipartimento di Scienze della Terra "Ardito Desio", Università degli Studi di Milano, Milano, Italy, 3. Istituto di Geologia Ambientale e Geoingegneria (IGAG), Consiglio Nazionale delle Ricerche, Montelibretti, Italy, 4. Dipartimento di Scienze della Terra (PaleoFactory lab.), Sapienza Università di Roma, Rome, Italy

Soil Micromorphology of Agricultural Terraces in Europe 1995

Dr. Daniel Fallu[1], Prof. Antony Brown [2]

1. The Arctic University Museum of Norway, UiT, The Arctic University of Norway, 2. Arctic University of Tromso

Floodplain dynamics, natural resources and human settlement change from the Archaic to the Postclassic in the Basin of Mexico. 1996

Dr. Kurt Heinrich Wogau Chong[1], Dr. Guillermo Acosta Ochoa [1], Dr. Carlos Cordova [2], Dr. Luis Morett [3], Dr. Tamara Cruz y Cruz [4], Dr. Philipp Hoelzmann [5]

1. National University of Mexico, Institute of Anthropology Investigations, 2. Oklahoma State University, 3. Universidad Autónoma Chapingo, 4. Escuela Nacional de Antropologia e Historia, 5. Freie Universität Berlin

Human-environment interactions in the Gete catchment (Belgium). An interdisciplinary approach. 1997

Ms. Marleen van Zon[1], Ms. Renske Hoevers [2], Dr. Ward Swinnen [2], Prof. Bart Vanmontfort [3], Prof. Gert Verstraeten [2]

1. KU Leuven, Department of Archaeology, Centre for Archaeological Research of Landscapes & KU Leuven, Department of Earth and Environmental Sciences, Division of Geography and Tourism, 2. KU Leuven, Department of Earth and Environmental Sciences, Division of Geography and Tourism, 3. KU Leuven, Department of Archaeology, Centre for Archaeological Research of Landscapes

Palaeoecological Evidence for the Domestication of the Wetlands of the Bolivian Amazon. 1998

Ms. Loretta-Ann Jilks[1], Dr. Neil Duncan [2], Dr. John Walker [2], Dr. Emma Hocking [1], Dr. Emma Pearson [3], Dr. Maarten van Hardenbroek [4], Prof. Bronwen Whitney [1], Dr. Michael Jeffries [1]

1. Geography and Environmental Sciences, Northumbria University, Newcastle, UK, 2. University of Central Florida, 3. Newcastle University, 4. Geography, Politics & Sociology, Newcastle University

Geoarchaeological study at the “Kakoryca-4” archaeological site (Southern Belarus) 1999

Mr. Dmitry Tsvirko[1], Dr. Tatyana Yakubovskaya [2], Prof. Piotr Kittel [3], Dr. Mikola Kryvaltsevich [4]

1. University of Lodz, Doctoral School of Exact and Natural Sciences, 2. Independent Researcher, 3. University of Lodz, Faculty of Geographical Sciences, Department of Geology and Geomorphology, 4. The National Academy of Sciences of Belarus, Institute of History

Multiple approach in palynological analyses to characterize human / environment dialectic in lakeshore environments: new data from the emerged sector of the early Neolithic site of La Draga (Banyoles, Spain). 2000

Ms. Liz Charton[1], Dr. Jordi Revelles [2], Dr. Isabel Expósito [3]

1. Muséum National d'Histoire Naturelle, 2. IPHES Catalan Institute for Human Palaeoecology and Social Evolution. Tarragona, Spain.; URV, Universitat Rovira i Virgili, Departament d'Història i Història de l'Art, 43002 Tarragona, Spain., 3. IPHES Catalan Institute for Human Palaeoecology and Social Evolution. Tarragona, Spain.

Late-Holocene climate change and the cultural landscape of Weipa, Australia 2001

Ms. Victoria Miller[1], Dr. Janelle Stevenson [1], Dr. Ulrike Proske [1]

1. ARC Centre of Excellence for Australian Biodiversity and Heritage; School of Culture, History and Language, The Australian National University

The impact of Early to Middle Bronze Age settlements and farming on vegetation, ecology, nutrient flux and sedimentation at Lake Lucone, northern Italy 2002

Dr. Giulia Furlanetto[1], Dr. Federica Badino [2], Dr. Renata Perego [3], Dr. Davide Abu El Khair [4], Dr. Marco Baioni [5], Prof. Roberto Comolli [4], Dr. Francesco Saliu [4], Dr. Cesare Ravazzi [3]

1. University of Milano-Bicocca, Dept. of Environmental and Earth Sciences / CNR-IGAG, Laboratory of Palynology and Palaeoecology, 2. University of Padova, Dept. of Geosciences / CNR-IGAG, Laboratory of Palynology and Palaeoecology, 3. CNR-IGAG, Laboratory of Palynology and Palaeoecology, 4. University of Milano-Bicocca, Dept. of Environmental and Earth Sciences, 5. Museo Archeologico della Valle Sabbia di Gavardo

Mountainous vegetation succession in the Peloponnese (Greece) during the last two millennia **2003**

Dr. Katerina Kouli[1], Ms. Grammatiki Vasiliadi [1], Dr. Georgios C. Liakopoulos [2], Dr. Alexandros Emmanouilidis [3], Mr. Ioannis Prevedouros [3], Prof. Pavlos Avramidis [3], Dr. Cristiano Vignola [4], Dr. Alessia Masi [5], Dr. Adam Izdebski [2]

__1.__ Department of Geology and Geoenvironment, National and Kapodistrian University of Athens, __2.__ Max Planck Institute for Geoanthropology, __3.__ Dept of Geology, University of Patras, __4.__ Dipartimento di Biologia Ambientale, Sapienza Università di Roma, Roma (Italy), __5.__ University La Sapienza

Vegetation and land-use history of the 'Kromme Rijn' area near Utrecht (Netherlands) during Roman and medieval times **2004**

Dr. Emmy Lammertsma[1], Mrs. Hendrike Geessink [2], Dr. Wim Hoek [3]

__1.__ BIAX Consult Biological Archaeology & Environmental Reconstruction, __2.__ Stichting Het Utrechts Landschap, __3.__ Dept. of Physical Geography, Faculty of Earth Sciences, Utrecht University

The Bisenzio Project: transdisciplinary investigation strategies to reconstruct human and palaeoenvironmental history of the Bolsena Lake (Central Italy) **2005**

Dr. Andrea Babbi[1], Dr. Alessandra Celant [2], Dr. Paolo Maria Guarino [3], Dr. Mauro Lucarini [3], Dr. Fabrizio Michelangeli [2], Dr. Giorgio Vizzini [4], Dr. Matteo Maggi [4], Dr. Sergio Bravi [5]

__1.__ Institute of Heritage Science of the National Research Council of Italy ISPC-CNR, Montelibretti Rome, __2.__ Dipartimento di Biologia Ambientale, Sapienza Università di Roma, Roma (Italy), __3.__ Dipartimento per il Servizio Geologico d'Italia - ISPRA, __4.__ Centro Nazionale per la rete nazionale dei laboratori - ISPRA, __5.__ Di.S.T.A.R., Università di Napoli Federico II.

The Lower Havel River and Greater Donaumoos Regions: 'Failed' or 'successful' reclamation of floodplains and peatlands? – A comparative analysis **2006**

Ms. Anne Köhler[1], Ms. Stefanie Berg [2], Dr. Michael Burkhart [3], Prof. Elisabeth Dietze [4], Prof. Kathryn Fitzsimmons [5], Dr. William Fletcher [6], Ms. Rita Gudermann [7], Dr. Knut Kaiser [8], Dr. Johannes Schmidt [9], Dr. Birgit Schneider [9], Dr. Willy Tegel [10], Prof. Anja Linstädter [11], Prof. Natascha Mehler [12], Dr. Ulrike Werban [13], Prof. Christoph Zielhofer [14]

__1.__ Institute of Geography, Leipzig University, Leipzig, __2.__ Bavarian State Department for Cultural Heritage, __3.__ Potsdam University, Botanical Garden; Potsdam, __4.__ Department Physical Geography, Georg-August-Universität Göttingen, __5.__ Department of Geosciences, University of Tübingen, __6.__ School of Environment, Education and Development, The University of Manchester, Manchester, United Kingdom, __7.__ Leibniz Institute for Research on Society and Space, Erkner, __8.__ Helmholtz Centre Potsdam, German Research Centre for Geosciences GFZ, __9.__ Institute of Geography, Leipzig University, __10.__ Albert-Ludwigs-Universität Freiburg, __11.__ Potsdam University, Institute for Biochemistry and Biology, __12.__ Institute of Prehistoric and Medieval Archaeology, Department of Medieval Archaeology, Tübingen University, Tübingen, __13.__ Helmholtz Centre for Environmental Research, Leipzig, __14.__ Universitat Leipzig

Interpreting the Holocene Deposits of the Niger River between Kotonkarfe and Idah in Northcentral Nigeria. **2007**

Dr. Tope Alege[1], Prof. Cornelius Nwajide [2]

__1.__ Department of Geology, Federal University Lokoja. Nigeria, __2.__ Geoscan Nigeria Limited

What do megadunes look like and how were they formed? A story from the glacial lake-outburst floods in NE Poland at the end of the Weichselian glaciation **2008**

Prof. Piotr Weckwerth[1], Prof. Wojciech Wysota [1], Prof. Jan Piotrowski [2], Prof. Arkadiusz Krawiec [1], Mr. Marek Chabowski [1], Prof. Edyta Kalińska [1], Mr. Aleksander Adamczyk [3]

__1.__ Faculty of Earth Sciences and Spatial Management, Nicolaus Copernicus University in Toruń, Lwowska 1, 87-100 Toruń, Poland, __2.__ Department of Geoscience, Aarhus University, __3.__ State Water Holding, PolishWaters RegionalWater Management Authority in Bydgoszcz, Al. A. Mickiewicza 15, 85-071 Bydgoszcz, Poland

Reconstruct the paleoenvironmental changes in the arid area: Imprints in the sediment from Olgoy lake, Mongolia **2009**

Dr. uyangaa udaanjargal[1], Prof. Noriko Hasebe [2], Prof. Davaadorj Davaasuren [1], Dr. Hitoshi Hasegawa [3], Dr. Katsuta Nagayoshi [4], Mr. Shuukhaaz Ganbat [5], Dr. Baasansuren Gankhurel [2], Prof. Fukushi Keisuke [2]

***1.** School of Arts and Sciences, National University of Mongolia, **2.** Institute of Nature and Environmental Technology, Kanazawa University, **3.** Faculty of Science and Technology, Kochi University, **4.** Faculty of Education, Gifu University, **5.** Division of Natural System, Institute of Nature and Environmental Technology, Kanazawa University*

Three decades (1986-2015) of thermokarst lakes/ponds shrinkage on the northeastern Qinghai-Tibet Plateau **2010**

Dr. Serban Raul-David[1], Prof. Huijun Jin [2], Dr. Mihaela Serban [3], Dr. Giacomo Bertoldi [1]

***1.** Institute for Alpine Environment, Eurac Research, Bolzano, **2.** Institute of Cold-Regions Science and Engineering, School of Civil Engineering, Northeast Forestry University, Harbin; School of Resources and Environment, University of Chinese Academy of Sciences, Beijing, **3.** Applied Geomorphology and Interdisciplinary Research Centre, Department of Geography, West University of Timișoara,*

Insights on the events surrounding the final drainage of Lake Agassiz-Ojibway based on high-resolution analyses of the Lake Matagami varve series (Québec, Canada) **2011**

Ms. Méliane Carrier-Favreau[1], Prof. Martin Roy [1], Dr. Patrick Lajeunesse [2], Dr. Pierre-Marc Godbout [3]

***1.** Geotop-Université du Québec à Montréal, Montréal, Canada, **2.** Université Laval, **3.** Geological Survey of Canada*

Constraining the contribution of Ungava-Labrador glacial lakes to early Holocene freshwater discharges: the case of Lake Cambrian in north-central Quebec (Canada) **2012**

Ms. Arianne Vallée[1], Prof. Martin Roy [1], Dr. Hugo Dubé-Loubert [2], Dr. Etienne Brouard [3], Dr. Joerg M. Schaefer [4]

***1.** Geotop-Université du Québec à Montréal, Montréal, Canada, **2.** Ministry of Energy and Natural Resources of Quebec, Val-d'Or, Quebec, **3.** Geological Survey of Canada, Natural Resources Canada, **4.** Lamont-Doherty Earth Observatory, Columbia University*

"Finis Ætatis Glacialis" – the drainage of the Central Jämtland Ice Lake and its connection to the Swedish Varve Chronology **2013**

Dr. Carl Regnéll[1], Dr. Sarah L. Greenwood [2], Dr. Richard Gyllencreutz [1], Dr. Gustaf Peterson Becher [3]

***1.** Department of Geological Sciences, Stockholm University, Sweden, **2.** Department of Geological Sciences, Stockholm University, 10691 Stockholm, Sweden, **3.** Geological Survey of Sweden*

Microscale Approaches to Studying Glaciolacustrine Sediments – lessons from Palaeolake Riada, Central Ireland **2014**

Dr. Cathy Delaney[1], Mr. Matthew Carney [1], Dr. Kathryn Adamson [1], Prof. PHILIP HUGHES [2]

***1.** Manchester Metropolitan University, **2.** The University of Manchester*

Reconstructing ice retreat of the south-eastern margin of the Laurentide Ice Sheet using proglacial lake sediments **2015**

Ms. April Howden[1], Dr. Timothy Lane [1], Dr. Kathryn Adamson [2], Dr. Matthew Finkenbinder [3], Ms. Erika Wintersteen [3], Mr. Robert Hawkins [3]

***1.** School of Biological and Environmental Sciences, Liverpool John Moores University, **2.** Manchester Metropolitan University, **3.** Wilkes University*

Geomorphological and palaeogeographical significance of infilled lake basins: insights from the Cordillera Blanca, Peru **2016**

Dr. Adam Emmer[1]

***1.** University of Graz*

2000 years of small glacier activity recorded by a proglacial lake in South-East Tibet **2017**

Mr. Francois Lemot[1], Dr. Pierre Sabatier [2], Dr. Marie-Luce Chevalier [3], Dr. Christian Crouzet [1], Ms. Lisa Kermagoret [4], Dr. Kévin Jacq [5], Prof. Patrick Rioual [6], Dr. Anne-Lise Develle [4], Dr. Mingkun Bai [7], Mr. Nathaniel Findling [8], Dr. Anne Replumaz [1]

1. Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, IRD, Univ. Gustave Eiffel, ISTerre, 38000 Grenoble, France, 2. Université Savoie Mont Blanc, CNRS, EDYTEM, 3. Key Laboratory of Deep-Earth Dynamics of Ministry of Natural Resources, Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, 4. Laboratoire EDYTEM UMR CNRS 5204 Université Savoie Mont Blanc, 5. Laboratoire Commun SpecSolE, Envisol – CNRS - Univ. Savoie Mont Blanc, Chambéry, 73000, 6. Key Laboratory of Cenozoic Geology and Environment, Institute of Geology and Geophysics, Chinese Academy of Sciences, 7. Key Laboratory of Deep-Earth Dynamics of Ministry of Natural Resources, Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China, 8. ISTerre, Université Grenoble Alpes, CS 40700 38058 GRENOBLE Cedex 9

Tracing Stone Tool Technology as Markers of Late Pleistocene Human Migrations in NE Asia and North America **2018**

Dr. Karisa Terry[1], Prof. Masami Izuho [2]

1. Central Washington Univeristy, 2. Tokyo Metropolitan University

New insights into subglacial processes in overdeepened settings revealed by swath bathymetry of young proglacial lakes **2019**

Mr. Siro Hosmann [1], Dr. Marius W. Buechi [2], Dr. Stefano Fabbri [3], Dr. Andreas Bauder [4], Prof. Flavio Anselmetti[3]

1. Institute of Geological Sciences and Oeschger Centre for Climate Change Research University of Bern, 2. Institute of Geological Sciences & Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland, 3. Institute of Geological Sciences and Oeschger Centre of Climate Change Research, University of Bern, Switzerland, 4. VAW ETH Zürich

Mapping submerged beachrocks using low-altitude aerial photogrammetry-UAV on the northern coast of the Sea of Marmara, NW Turkey **2020**

Mr. Mustafa Geyik[1], Dr. Ufuk Tari [1], Prof. Orkan Özcan [2], Prof. Gursel Sunal [1], Prof. Cenk Yaltirak [1]

1. Department of Geological Engineering, Faculty of Mines, Istanbul Technical University, 34469, Istanbul, Turkey, 2. Istanbul Technical University, Eurasia Institute of Earth Sciences, 34469 Maslak, Istanbul

First pollen record from the Late Holocene forest environment in the Lesser Caucasus **2021**

Dr. Sébastien Joannin[1], Dr. Vincent OLLIVIER [2], Prof. Olivier BELLIER [3], Mr. Benoit Brossier [4], Dr. Brice Mourier [5], Dr. Petros Tozalakyan [6], Dr. Claude Colombié [7], Dr. Maxime Yevadian [8], Dr. Boris Gasparyan [9], Dr. Ariel Malinsky-Buller [10], Dr. Christine Chataigner [11], Dr. Bérengère Perello [12]

1. Institut des Sciences de l'Évolution de Montpellier, University of Montpellier, CNRS, EPHE, IRD, 2. LAMPEA (UMR 7269; CNRS-Aix Marseille Université, Ministère de la Culture et de la Communication), MMSH 5 rue du Château de l'Horloge, 13094 Aixenenrovence, France, 3. Aix Marseille University, CNRS, IRD, INRAE, College de France, CEREGE, Aix-en-Provence, France, 4. ISEM, Univ Montpellier, CNRS, IRD, Montpellier, 5. LEHNA, Université Lyon 1, ENTPE, 6. Institute of Geological Sciences of the National Academy of Sciences of Armenia, 7. Univ. Lyon, UCBL, ENSL, UJM, CNRS, LGL-TPE, F-69622, Villeurbanne, 8. CNRS d'HiSoMA, UMR 5189, Lyon, 9. Institute of Archaeology and Ethnography, National Academy of Sciences of the Republic of Armenia, Yerevan, Armenia, 10. The Institute of Archaeology, The Hebrew University of Jerusalem, Jerusalem, 11. Laboratoire Archéorient Maison de l'Orient et de la Méditerranée, Université Lyon 2, 12. Laboratoire Archéorient Maison de l'Orient et de la Méditerranée, Université Lyon 2,

Evidence for an Illinoian (MIS 6) aged 3,500 km2 proglacial lake in the Midwestern United States **2022**

Ms. Sadie Richter[1], Mr. Phillip Kerr [2]

1. University of Iowa, 2. Iowa Geological Survey

Human-animal interaction in the Harappan Civilisation: regional distribution of domesticated animals and an evaluation of current research practices **2023**

Mr. Siddharth Kutty [1], Dr. Kalyan Sekhar Chakraborty[1]

1. Ashoka University

Sclerochronology of pectinids from the warm Mediterranean Pliocene: what can we learn about species response to future climate change? **2024**

Dr. Silvia Danise[1], Ms. Giada Giachetti [1], Dr. Ilaria Baneschi [2], Dr. Martina Casalini [1], Dr. Francesco Miniati [1], Dr. Stefano Dominici [3], Dr. Chiara Boschi [2]

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The stratigraphy and sedimentology of the Roman-Byzantine El-Araj archaeological site at the northern coast of the Sea of Galilee, NE Israel **2025**

Prof. Noam Greenabum[1], Dr. Nathaniel Bergman [2], Prof. Mordechai Aviam [3], Prof. Steven Notley [4]

1. University of Haifa, Haifa, 3498838, Israel, 2. University of Haifa, Haifa 3498838, Israel, 3. Kinneret Institute for Galilean Archaeology, Land of Israel Studies, Kinneret College on the Sea of Galilee, Israel, 4. Alliance University New York, NY 10004

Poster - sessions 10, 38, 56, 78, 95, 107, 108, 109, 115, 121, 180, 182, 184, 187

The 3D Pollen Project: super-resolution scanning a representative sample of the world's pollen diversity in two and three dimensions **2027**

Dr. Oliver Wilson[1], Prof. Robert Marchant [1]

1. University of York

PalaeoScope: an augmented reality app for visually telling stories about the past **2028**

Dr. Georgios Lyras [1], Mr. Emmanuel Galanopoulos [2], Mr. Nikolaos Karydas [2], Mr. Alexandros Iakovidis [2], Mr. Konstantinos Paraskevopoulos [2], Mr. Konstantinos Gelegenis [2], Dr. Georgia Kotzamani [1], Dr. George Kontakiotis [1], Ms. Evangelia Besiou [1], Mrs. MYRSINI VOULGARI[1], Ms. Alexia Grambas [1], Ms. Vasiliki Alexoudi [1], Mr. George Sofianopoulos [3], Prof. Assimina Antonarakou [1]

1. National and Kapodistrian University of Athens, 2. InDigital, 3. Foundation of the Hellenic World

Climate change – the boardgame: a free educational resource to discuss paleoclimate, evolution and conservation **2029**

Dr. Michela Leonardi[1], Prof. Andrea Manica [1]

1. Department of Zoology, University of Cambridge

Challenges and opportunities in communicating interdisciplinary paleoscience **2030**

Ms. Giorgia Camperio[1], Dr. Maria Elena Castiello [2], Dr. Ignacio Jara [3], Prof. Thijs van Kolfschoten [4], Dr. Katarzyna Marcisz [5], Ms. Daniela Moraga Lopez [6]

1. Geological Institute, ETH Zürich, 2. Institute of Archaeological Sciences (IAW) University of Bern, 3. Centro de Estudios Avanzados en Zonas Áridas (CEAZA), 4. Faculty of Archaeology, Leiden University, Einsteinweg 2, 2333, CC, the Netherlands, 5. Climate Change Ecology Research Unit, Faculty of Geographical and Geological Sciences, Adam Mickiewicz University, Poznań, Poland, 6. Pontificia Universidad Católica de Chile

Communicating Quaternary science to community collaborators in Timor-Leste **2031**

Dr. Simon Connor[1], Dr. Frederico Santos [2], Dr. Sarita Camacho [3], Dr. Larissa Schneider [1], Dr. Susan Rule [4], Ms. Zoë Taylor [5], Mr. André Aleixo Araújo [6], Prof. Simon Haberle [1]

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A timeline for the history of Quaternary studies in Italy from Arduino to the nineteen-seventies **2032**

Prof. Giuseppe Orombelli [1], Prof. Maria Rita Palombo [2], Dr. Renata Perego [3], Dr. Cesare Ravazzi[3]

1. University of Milano Bicocca, Department of Environmental and Geological Sciences, 2. CNR IGAG, 3. CNR-IGAG, Laboratory of Palynology and Palaeoecology

If lakes could tell stories...: an illustrated children’s book about Palaeolimnology **2033**

Dr. Celia Martin-Puertas[1]

1. Royal Holloway, University of London

PollenScape: a tactile teaching and engagement tool for visualising landscapes of the past. **2034**

Dr. Janelle Stevenson[1], Dr. Kelsie Long [1], Dr. Elle Grono [2], Dr. Simon Connor [1], Dr. Rebecca Hamilton [3]

1. ARC Centre of Excellence for Australian Biodiversity and Heritage; School of Culture, History and Language, The Australian National University, 2. School of Archaeology and Maritime Cultures, University of Haifa, 3. Max Planck Institute for Geoanthropology

Science communication for community engagement in Australian Quaternary Science. **2035**

Ms. Kelsey Boyd[1], Dr. Haidee Cadd [1], Dr. Emma Rehn [2], Mr. Alexander Wall [3], Ms. Jacqueline Wales [1]

1. ARC Centre of Excellence for Biodiversity and Heritage, School of Earth, Atmospheric and Life Sciences, University of Wollongong, 2. College of Science and Engineering, James Cook University, QLD, Australia & ARC Centre of Excellence for Australian Natural and Cultural Heritage CABAH, 3. Australian National University

Painted Stories of Norway Spruce Migratiion in Scandinavia **2036**

Dr. Laura Parducci[1], Dr. Kevin Nota [2], Dr. Jill Pelto [3]

1. Department of Environmental Biology, Sapienza University of Rome, 2. Department of Evolutionary Genetics, Max Planck Institute for Evolutionary Anthropology, Deutscher Platz 6, 04103 Leipzig, Germany, 3. University of Maine

InSAR surface deformation, geological structure and fault model of the 2019 Mirpur earthquake. **2037**

Mr. Divya Sekhar Vaka [1], Dr. Tejpal Singh[2], Dr. Y. S. Rao [1]

1. Centre of Studies in Resources Engineering, Indian Institute of Technology Bombay, Mumbai, 2. CSIR-Central Scientific Instrument Organisation, Chandigarh

Reassessing the oldest archaeological evidence of Colombia **2038**

Dr. Brunella Muttillo[1], Dr. Ettore Rufo [2], Prof. Roberto Lleras Pérez [3], Dr. Giuseppe Lembo [2]

1. Dipartimento di Scienze Fisiche, della Terra e dell’Ambiente, Università degli Studi di Siena, 2. Ministero dell’Istruzione e del Merito, 3. Academia Colombiana de Historia, Bogotá

Techno-economic approach to early lithic industries of Fuego-Patagonia: dynamic interactions among culture, society and the environment at Finis Terrae (50º-56º South Latitude) 2039

Dr. Flavia Morello[1], Dr. Consuelo Huidobro [2], Dr. Fabiana María Martin [3], Dr. Luis Alberto Borrero [4], Dr. Marianne Christensen [5], Dr. Marta Alfonso Durruty [6], Dr. Mauricio Massone [7], Dr. Ismael Martínez [7], Dr. Robert McCulloch [8], Dr. Claudia Mansilla [9], Dr. Jimena Torres [1], Dr. Victor Sierpe [1], Dr. Manuel san román [1]

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Early maritime peopling of the Pacific tundra and the first archaeological records from Brecknock Peninsula, Tierra del Fuego (54ºS/72ºW) 2040

Dr. Manuel san román[1], Prof. Svante Björck [2], Dr. Björn Nilsson [3], Dr. Arne Sjöström [4], Dr. Luis Alberto Borrero [5], Dr. Valentina Trejo [6], Dr. Ismael Martínez [6], Dr. Robert McCulloch [7], Dr. Consuelo Huidobro [8], Dr. Jimena Torres [9], Ms. Javiera Mardones [10], Mr. Erik Lukoviek [11], Dr. Flavia Morello [9]

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Can we use geochemical signals to link tsunami deposits and seismo-turbidites in a coastal lake system? First results from Lakes Cucao and Huillinco (northern Chilean Patagonia) 2041

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Session 2: Recent advances in understanding the causes of changes in regional and global palaeofire regimes: resources, tools and new approaches

Global fire modeling and its potential for paleo fire research

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Fires are an integral part of the Earth System, with the first proxies of fire being found soon after the advent of land plants. Fire frequency has varied widely over the course of the Quaternary Period due to changes in climate, vegetation, and, more recently, anthropogenic impacts. To understand how changes in these drivers, and their interactions, influence the occurrence of wildfires, multiple global fire models have been developed over the course of the last decades. These models vary in the number and complexity of processes represented, with a wide variety of model structures currently available. Global fire models have been incorporated into land-surface and dynamic vegetation models, enabling the representation of fire-vegetation feedbacks, and the potential for these models to project past and future changes in fire occurrence. Here I will give an overview of the current status of global fire models, I will discuss the strengths and weaknesses of the current generation of these models and, finally, I will focus on the potential to use them in paleo fire research.

Exploring the sensitivity of global fire regimes to atmospheric CO2 levels at the Last Glacial Maximum

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The occurrence of wildfires is influenced by climate, vegetation properties, ignition sources and human activities. Generalised linear models (GLMs) have been developed to predict the spatial patterns in burnt area, fire size and fire intensity under modern conditions. Such models could be used to predict how wildfire regimes will respond to future changes in climate. One issue raised by such an application is that gross primary production (GPP), which is critical for determining fuel loads, is influenced by climate and also sensitive to changes in atmospheric CO_2 levels.
Here we explore the effect of climate and CO_2 levels on fire regimes at the Last Glacial Maximum (LGM; 21 ka BP), when climate was colder and drier and CO_2 levels were around 185 ppm. We used outputs from three Palaeoclimate Modelling Intercomparison Project climate models, AWIESM2, CESM1.2 and MPI-ESM1.2 to provide a range of simulated LGM climates. Vegetation distribution under these three climate-change scenarios was simulated using the BIOME4 biogeography model and GPP using the P model, a light-use efficiency model which accounts for the physiological effect of CO_2 on productivity. The LGM simulations were compared to a modern-day control simulation with the impact of human activity on wildfires excluded. We conducted two sensitivity experiments to separate the impacts of climate changes from those of lower CO_2, firstly using LGM climate with modern CO_2 levels and secondly using modern climate with LGM CO_2 levels.
The LGM simulations show a global decrease burnt area, with all three climate scenarios compared to modern day, consistent with the observed reduction in wildfire. Comparison with charcoal records from the Reading Palaeofire Database shows the models reproduce regional patterns, both in regions where fire was reduced compared to present and in the more limited areas (e.g. southern China, Alaska) where wildfire was increased. The sensitivity experiments show that low CO_2 levels were key to obtaining realistic reductions in burnt area, since the simulation using LGM climate with modern CO_2 produced much higher levels of burning. These results highlight the importance of accounting for the effect of atmospheric CO_2 on vegetation when projecting future changes in wildfires.

Developing Novel Proxies for Reconstructing Past Fire Histories in South-eastern Australia

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Fire is endemic in the Australian landscape, shaping biodiversity and ecosystem change for millennia. As climate change continues to modify fire regimes at local to national scales, bushfires are forecast to increase in severity, intensity and area burnt. However, our existing records primarily rely on remote sensing data, which is limited to the satellite era or the analysis of charcoal and dendrochronological records, which can inform on fire occurrence but do not detect fire characteristics such as severity and intensity. Therefore, to more accurately forecast future fire events and determine whether recent large-scale events, such as the 2019-20 Black Summer Bushfires in southeastern Australia, are the new normal standard, there is an urgent need to develop new tools that can distinguish fire characteristics. Boron isotopes and Fourier Transform Infrared (FTIR) spectroscopy lend themselves as potential proxies due to their sensitivity to changes in vegetation cover and chemical bonds, respectively.

The Upper Blue Mountains in New South Wales (NSW) and Namadgi National Park in the Australian Capital Territory (ACT) are notoriously fire-prone and provide an opportunity to calibrate these techniques. Samples have been collected from sediment reservoirs, including large-order creek beds and swamps, and a radiocarbon-based age-depth model has been paired with results from these two proxies to formulate a long-term record of past fire events. Preliminary results demonstrate an increase in the $\delta^{11}B$ value of sedimentary layers burnt at high severity. This increase results from ash deposition enriched in leaf material and ^{11}B. These layers also exhibit an increase in the aromatic/aliphatic ratio as long-chain aromatic compounds are the first to be decomposed when heated, forming more temperature and decomposition-resistant aromatic compounds. These techniques have the potential to be applied to other national and global fire hotspots to better understand how fire regimes have evolved through time and allow for improved mitigation of and recovery from future fire events.

Capturing wildfire and vegetation gradients along the West African margin in marine sediments: a biomarker approach

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Biomass burning has significant impacts on the global carbon system both via emissions of CO_2 and aerosols into the atmosphere and through complex feedbacks with climate and terrestrial vegetation. Organic molecular indicators of combustion—-fire biomarkers—-have become an increasingly useful set of tools for reconstructing the history of biomass burning in order to better understand wildfire variability in various environments and back in time. Previous paleofire work has focused primarily on lacustrine archives, while marine sediments have received less attention. Here we demonstrate that two classes of fire biomarkers, pyrosugars and polycyclic aromatic hydrocarbons (PAHs), preserved in core top sediments along the West African Margin (40°N–34°S) record modern latitudinal gradients of biomass burning on the Iberian Peninsula and along the West African margin. Fire biomarkers normalized to *n*-alkane terrestrial plant waxes reveal higher instances of fire in grassier ecosystems consistent with modern satellite observations. The relative abundance of pyrosugars compared to PAHs broadly reflected the relative proportion of small vs large fires in core top source areas, lending support to its use as a fire intensity proxy. Distribution-based metrics of these compounds often used as fuel source estimators seem to fail in Africa perhaps due to sampling biases in the underlying burn experiment datasets. Plant-wax normalized pentacyclic triterpene methyl ethers (PTMEs), a class of biomarkers especially prevalent in grasses, shows good spatial agreement with the presence of C_4 grasses in particular, while differences between PTMEs and plant-wax $d^{13}C$ suggests shorter transport distances for PTMEs. Deviations from the zonal structure of fire and vegetation on the adjacent landscape within the marine core top transect can mostly be attributed to long-range transport estimated using back-trajectory modeling.

Late Holocene land cover and fire dynamic in Bad Waldsee (SW Germany) mirrored in seasonally laminated sediments and historical archives

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Lakes close to human settlements offer excellent archives to investigate the mutual relationship between long-term environmental changes and human activities. The Bad Waldsee project uses the rare spatial proximity of a historically well-documented medieval town and its central lake (Stadtsee) to reconstruct the socio-environmental developments of the city and its periphery during the preindustrial phase of 750-150 cal. Yr BP, the late Medieval period to Modern Times, respectively. The fire events for this time span have been studied using micro- and macro-charcoal records from the Stadtsee sediments. Macro charcoal results showed 15 screened charcoal peaks, which grouped into two phases of biomass burning. The detected burning episodes were compared with regional paleofire trends and interpreted using sedimentological, palynological, and historical data. The first phase in the late Medieval period (653-533 cal. Yr BP) showed high proportions of burned grass and monocot leaves. This phase is followed by a distinct interval of no-burning (533-313 cal. Yr BP) that coincides with the flourishing of the textile industry, cultivation, and processing of cannabis in the vicinity of the Medieval Bad Waldsee. The second phase from 313 cal. Yr BP onwards represents Modern Times with wood as the primary fire fuel. Reconstructed periods of low-magnitude local fires during the late medieval times and after 1750 AD (200 cal. Yr BP) coincided with changes in the type and intensity of land use. Major local and regional historical events like the Thirty Years' war and the fire incident near the town (1386 AD - 174 cal. Yr BP) are also documented by the charcoal sedimentary record. Combined with a previously studied sequence, the entire Stadtsee sediment record allows exploring the role of fire in the central European landscape from prehistory (4000 cal. Yr BP) up to Modern Times. The fire signals from the Bronze Age to the Medieval Period are presently being studied and will be interpreted using a multiproxy approach.

High-resolution biomarker imaging reconstructs 2,000 years of southern California wildfire history

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Southern California has been prone to wildfires throughout its history. Exploring the natural variability of wildfire in this region and understanding their large-scale drivers requires wildfire reconstruction at high temporal resolution that extends beyond the limited historical record. High-accumulation varved sediment deposits from the center of Santa Barbara Basin (SBB) off California provide an ideal archive for paleofire reconstruction. However, typical reconstructions using charcoal or biochemical tracers require discrete sampling of the sediment record, limiting the temporal resolution of wildfire records to multi-year analyses. With mass spectrometry imaging (MSI) using laser desorption ionization coupled to Fourier transform-ion cyclotron resonance-mass spectrometry, geochemical fire tracers such as the monosaccharide anhydride (MA) levoglucosan and its isomers mannosan and galactosan can be analyzed on intact SBB sediment sections at sub-mm spatial, and thus interannual temporal resolution.
To assess the feasibility of MSI for high-resolution wildfire reconstruction, a SBB core spanning AD 1900 - 2009 (SPR0901-05BC) was analyzed to enable comparison with observational and reanalysis datasets. The resulting MSI-based record of MA intensity bears a strong resemblance to the areal extent of historically recorded wildfires in this region. In addition to the targeted analyses of MA, we applied untargeted data analysis routines on the MSI dataset to identify additional compounds with distinct distributions indicative of wildfire occurrence or that align with wildfire-facilitating parameters such as vapor pressure deficit. We identified organic acid-like compounds related to wood-burning aerosols that strongly correlate to the MA signal, and thus to the burned area in this region. We additionally applied MSI of fire biomarkers to SBB sediment core MV0811-14TC, comprising the last two millennia. The 100-µm-scale MSI analyses provide sub-annual wildfire and environmental proxies, e.g., sea surface temperature, to examine high-frequency changes in past southern California fire regimes during different periods such as the Medieval Climate Anomaly, Little Ice Age, and Settlement Era.

Revisiting Tswaing Crater: an eco-evolutionary interpretation of fires influence on vegetation assembly in an ancient African grassy ecosystem

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Previous fossil pollen and charcoal studies from Tswaing Crater's ~ 230 kyr sedimentary basin in South Africa's grassy biome focused on how climate shaped past vegetation dynamics. While these studies shaped our understanding of past vegetation-climate dynamics; however, high climatic variability in the warm tropics is associated with strengthened roles of disturbance processes from fires, large herbivores, and humans. Recent studies highlight positive disturbance-vegetation interactions as vital for maintaining open grass-dominated mosaic landscapes with high heterogeneity and biodiversity by filtering out plants and animals according to tolerance or avoidance traits. Flammability is considered a key plant trait linked with abilities of individuals or communities to persist in frequently burned open ecosystems where fires are mainly driven by grass fuel loads and limited by tree canopy cover. This often leads to alternate trait-driven stable vegetation community states from patch to biome level. Here, we revisit the Tswaing pollen and charcoal records through the lenses of plant functional traits to identify flammability, tree canopy cover, and grass fuel load gradients. Results from primary axes of two contrasting ordination methods suggested vegetation dynamics were largely driven by grass abundance (Poaceae). Along the primary axes, alternate flammable savanna and fire-sensitive forest taxa occurred at opposite ends with non-overlapping convex hulls. Micro-charcoal abundances along primary axes increased in the direction of savanna taxa. Interestingly, from ca. 75.3 kya, sediment $\delta^{13}C$ values were more positive and micro-charcoal increased, indicating frequent fires, wetland drying, and/or incursions by landscape C_4 taxa. Periods of high Zr/Rb from ca. 162-44 kya, an indicator of soil disturbance possibly caused local herbivory or wetland manipulation corresponded with low micro-charcoal abundance. Furthermore, Artemisia-type pollen associated with forbs and herbivory in open landscapes suggested local biotic disturbances. Together, our results show that pollen and other proxies can be interpreted using plant functional traits underpinned by ecological-evolutionary processes. A shift towards trait-based approaches could be beneficial for reinterpreting past landscapes changes and benefit the restoration of open ecosystem processes in the Anthropocene.

Session 3: Orbital and millennial vegetation changes at global and regional scales during the Quaternary: insights from data and models

Diverse response of global terrestrial vegetation to astronomical forcing, CO2 and ice sheets from orbital to millennial timescales

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During the Quaternary glacial-interglacial cycles, the spatial distribution of major vegetation types on the globe was strongly affected by the astronomically-induced changes in latitudinal-seasonal distributions of insolation and by the changes in atmospheric CO_2 concentration and ice sheets. However, the relationship between vegetation and different forcing factors remains complex and not necessarily well understood. In this study, we investigate the vegetation variations on orbital and millennial timescales and their relationship with different factors by combining proxy reconstructions and model simulations. Three representative glacial-interglacial (G-IG) periods, i.e. MIS19-18, MIS13-12 and MIS11-10, which are characterized by different variations of precession, obliquity, CO_2 and ice volume, are chosen.

Our results show that the relative effect of precession and obliquity on vegetation strongly depends on regions and also varies between the G-IG periods. For example, in the subarctic and Mediterranean regions and over most of the mid-latitude lands, obliquity is more important than precession during MIS11-10 due to large variations of obliquity and small variations of precession, whereas by contrast, precession is more important than obliquity in these regions during MIS13-12. Over eastern Africa, Indian subcontinent and East Asia, precession is more important during both MIS11-10 and MIS13-12. Our results show that astronomical forcing plays a dominant role on regional vegetation evolution as compared to CO_2. As quite expected, large Laurentide and Eurasian ice sheets suppress forest and favor grass development over many regions, but exceptions exist and the sensitivity of vegetation response to ice sheets strongly depends on regions. Our transient simulations also reveal the subharmonics of precession signal in the vegetation evolution in the tropics and some extra-tropical regions such as the Mediterranean, but the occurrence and strength of these signals depend on regions and vary in time.

In addition to orbital and sub-orbital scale variations, the astronomically-induced slow variation of insolation could induce abrupt changes and multi-centennial variations in the forest and grass compositions especially in the northern mid-high latitudes. When boreal summer insolation decreases to a threshold, it induces abrupt changes in the AMOC, which in turn affects the climate and vegetation at large continental scale.

Reconstruction of atmospheric CO2 concentration over the past 1.5 million years based on leaf wax (long-chain n-fatty acid) carbon isotope record from the Bay of Bengal.

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Atmospheric CO_2 and polar ice volume have been strongly coupled over the past 805,000 years. However, the prior extent of coupling, during times of lower-amplitude ice-volume variability before 805,000 years ago, is unknown because continuous high-resolution CO_2 records are lacking. We reconstructed the past 1,460,000 years of atmospheric CO_2 (~1,700-year sample resolution) by taking advantage of the unique relationship between CO_2concentration and leaf wax $\delta^{13}C$ at IODP Site U1446 resulting from changes in the extent of C_3 and C_4 vegetation in East India. The results indicate that reconstructed interglacial CO_2 concentrations were lower before the transition to large volume variability during the mid-Pleistocene transition (MPT; 900,000 years ago). Prior to the MPT, CO_2 had a secular trend similar to that of deep-ocean carbon isotopes. At orbital time scales, phase analysis indicates that the CO_2 lead relative to ice volume changed to a lag during the MPT. Combined, these findings suggest that deep-ocean circulation controlled the long-term CO_2 trend, and that interaction between CO_2, continental ice, and deep-ocean circulation was reorganized during the MPT, involving a decrease in the carbon storage in the deep Pacific.

Holocene history of the vegetation of the Eastern Mediterranean region

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There are unsolved questions about the Holocene vegetation history of the eastern Mediterranean, including 1) whether vegetation assemblages in the transition from the Late Glacial to the early Holocene have modern-day analogues, 2) whether postglacial reforestation was delayed in the eastern part of the region, 3) what was the geographical extent of temperate deciduous forest at the mid-Holocene, and 4) what were the timing and causes of the re-establishment of drought-tolerant vegetation during the late Holocene. Here we address these questions by using a recently developed pollen-based vegetation reconstruction technique that accounts for within-biome variability in the abundances of pollen taxa to assign fossil pollen samples from 137 records to the biome with which they have the greatest affinity allowing us to reconstruct eastern Mediterranean (33°-49°N, 20°-60°E) vegetation since 12 ky. In addition, we use per-biome threshold values to identify samples that do not belong to any modern biome. We analyse these vegetation reconstructions to examine space and time vegetation dynamics using time series analysis, break-point analysis and mapping. Our results shows that sites with non-analogue vegetation were most common between 11.5 ky and 9.5 ky and mostly in the Carpathian region. The early Holocene change from open vegetation to forest occurred at 10.58 ± 0.74 ky; the eastern records do not show a consistent delay in forest development with respect to the western records. Temperate deciduous forest was more extensive at 6 ± 0.2 ky but the maximum expansion was recorded in the 5.5 ± 0.2 ky and 5 ± 0.2 ky time windows. The peak in the number of forest sites occurred between ca. 4 and 2.8 k and was followed by an abrupt decrease, and this pattern is consistent with speleothem oxygen isotope records from the region. This work provides new insights into debated issues about regional vegetation changes, including the prevalence of non-analogue vegetation during the late glacial and early Holocene, and the expansion of moisture-demanding temperature trees in the mid-Holocene. Although there is no strong signal of late Holocene aridification, changes in the amount of forest are more consistent with climatic changes than anthropogenic influences.

Tracking postglacial expansion of European trees

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Integrating pollen records over large spatial scales allows tracking range expansions and contractions of plant species in response to environmental changes in time and space. Even though the creation of isopollen or isochrone maps has a long history in paleoecology, the increasing number of sites, higher chronological precision, and the improved data accessibility in regional or global databases permits to study vegetation dynamics in ever greater detail. Due to ease of data processing, most recent maps are based on pollen percentage thresholds to estimate the first local presence of a taxon. However, this approach is not clearly linked to ecological processes of population dynamics. Instead, we argue that using established biostratigraphic patterns in pollen records, such as the absolute, empirical, and rational limit, would be better suited to infer ecological dynamics such as local population establishment or mass expansion.

Here, we present species maps tracking the local establishment of 29 arboreal pollen taxa for the last 20,000 years based on a curated set of 323 representative pollen records throughout Europe. We also calculated isochrones based on geographic interpolation techniques. The maps highlight the location of refugia of subtropical, temperate, and boreal species during the Last Glacial Maximum and document subsequent range expansion in response to rapid warming during the Lateglacial and Holocene. To our knowledge, the postglacial spread of several Mediterranean species is captured for the first time at the European scale. On the basis of the isochrone maps, we also estimated spreading rates and dispersal distances for all taxa. This assessment is particularly relevant to check if tree species are able to respond fast enough to ongoing and future climate change.

Impacts of the slowdown of the Atlantic meridional overturning circulation over Amazonian vegetation

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The Atlantic meridional overturning circulation (AMOC) is a core-tipping element of the climate system that may exceed a critical threshold within a societal-relevant future substantially slowing down and changing global atmospheric circulation. In modern climate, the AMOC regulates precipitation over tropical South America, but the impact of an AMOC slowdown over the Amazon rainforest, another core-tipping element of the climate system, remains unclear. During the last deglaciation, a shutdown of the AMOC (i.e., Heinrich Stadial 1) promoted drier and more seasonal rainfall conditions in northern Amazonia, where modern deforestation and wildfires are less pronounced than in southern Amazonia. Here, we investigate the Amazonian vegetation response to this natural experiment based on pollen and microcharcoal analyses of marine sediment core GeoB16224-1 (6°39.38'N, 52°04.99'W) and species distribution models forced by fully coupled climate models. The pollen analysis of the interval 25–12.8 ka reveals that Amazon vegetation undergone striking changes. During the Last Glacial Maximum, the combination of a significantly colder and relatively drier climate, lower atmospheric CO_2 concentrations, and ca. 120 m lower sea-level transformed the Amazonian landscape. Nevertheless, the Amazon basin remained mostly covered by forests that, however, showed a distinctly different vegetation composition characterized by the expansion of cold- and moist- affinity tree elements. During Heinrich Stadial 1, our data suggest a loss of tropical rainforest suitability over northern Amazonian and a decline in cold- and moist- affinity taxa that occupied the lowlands, while the overall fraction of herbs increased and other major vegetation groups remained relatively stable. Despite the forest cover changes in northern Amazonia, the rainforest was resilient to rainfall shifts in the rest of the basin, related to the past AMOC shutdown. Importantly, our findings indicate northern Amazonia is likely the most vulnerable portion of the rainforest for a future AMOC slowdown. Given the extensive anthropogenic land cover changes already promoted in the southern and eastern portions of the basin, we suggest that a negative synergy between deforestation, wildfires, climate change and AMOC slowdown will bring the Amazon rainforest dangerously close to its tipping point in the near future, if anthropogenic forcings remain unabated.

Centennial-scale climate and ecosystem variability in SE Europe since the Early Pleistocene based on the Tenaghi Philippon archive (Greece)

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The limnotelmatic sequence of Tenaghi Philippon (NE Greece) has been recognized since the 1960's as a unique archive of terrestrial climate and ecosystem dynamics for the Quaternary in Europe. We have retrieved and evaluated new sediment cores from Tenaghi Philippon that span the past c. 1.4 Ma continuously based on a vegetation-independent chronology derived by the integration of radiocarbon dating, tephrochronology, magnetostratigraphy, and cyclostratigraphy. These efforts have resulted in a new pollen-based record of Mediterranean ecosystem dynamics at (sub-)centennial temporal resolution (mean: c. 250 years) covering the past ten glacial-interglacial cycles, i.e., ranging from Marine Isotope Stage (MIS) 1 through MIS 21. The vegetation data are augmented by decadal-scale resolution (c. 30 years) XRF-based element geochemical data that provide insight into precipitation variability. The exceptionally high temporal resolution of our datasets and the high-quality age control allow reconstruction of the vegetation response to climatic forcing at time scales that are comparable to the rapidity of present-day and near-future anthropogenic climate change. Our analysis documents two stable vegetation regimes across a wide range of moisture levels, with abrupt shifts from forest to steppe biomes occurring when a threshold in precipitation was crossed. Our results demonstrate that the demise of Mediterranean forests across the Middle and Late Pleistocene ("100-kyr world") occurred within decades and hence shed new light on the vulnerability of Mediterranean forests to the recurring droughts as they are projected for the Mediterranean region in the near future. Ongoing analysis of the lower part of the sequence from MIS 22 to MIS 45 ("41-kyr world") will provide information on whether the dependence of forest biomes on moisture availability persisted during the early Pleistocene at Tenaghi Philippon or whether it was intiatiated across the Mid-Pleistocene Transition following reorganizations in global climate dynamics.

Before the Early Middle Pleistocene Transition: insights on the environmental variability and explosive activity in central Italy during the 1.5-2.1 Ma interval from the L'Aquila Basin lacustrine record

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The Quaternary climate is featured by a notable change in frequency and amplitude of the glacial-interglacial cycles, known as the Early Middle Pleistocene Transition (EMPT), which since ~1.25 Ma to ~0.70 Ma gradually shifted from the quasi-symmetrical and weak amplitude cycles with a 41 kyr periodicity, to the strongly asymmetric, high amplitude cycles with a 100 kyr periodicity. While many records from different environmental settings are available for the post-EMPT period, still little is known for the longer Quaternary history preceding the EMPT, mostly because of the scarcity of high-resolution and precisely dated archives spanning this interval. The lacustrine successions hosted in post-collision tectonic basins of the central Apennines, central Italy, have proven to be valuable archives of the dynamic and evolution of the regional climate, ecosystems, volcanism and tectonics during Quaternary. Here we present a new record from a 230 m-long core recovered from the lacustrine succession of the L'Aquila Basin, at Castelnuovo (CN) site. A multi-method dating approach, combining tephra $^{40}Ar/^{39}Ar$ dating, paleomagnetic stratigraphy, and the glacial-interglacial cyclical expression of paleoenvironmental proxy data indicate that the whole CN succession spans the period ~1.5 Ma to ~2.1 Ma; i.e., 600 kyr of history shortly preceding the start of the EMPT. The multi-proxy data from CN sediment core, including major and trace element and Sr-Nd isotope composition of the glass from six tephra layers, and $CaCO_3$ content, scanning XRF element geochemistry, $\delta^{18}O_{calcite}$,clumped isotopes, and pollen analyses from the lacustrine sediments, provided us with a new record of the environmental-climate variability in central Italy spanning twelve glacial-interglacial cycles, from marine isotope stage (MIS) 51 to MIS 78, as well as the first distal evidence of the earliest known calc-alkaline volcanic explosive activity in Campanian Plain.

Session 4: Bridging earthquakes over time scales – from the seismic cycle to Quaternary landscape evolution: contributions from the EDITH INQUA-TERPRO-Terrestrial Processes, Deposits and History Project

Spatial migration of temporal earthquake clusters driven by the transfer of differential stress between neighbouring fault/shear-zone structures.

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Uncertainty about the processes responsible for slip-rate fluctuations associated with temporal earthquake clustering is one of the most fundamental, unresolved issues in tectonics, because (a) the strain-rates accommodated by fault/shear-zone structures are the key to understanding the viscosity structure of the crust and hence crustal rheology and evolution, and (b) the strain-rates, and their variability in space and time, control the spatial and temporal occurrence of hazardous earthquakes. In this study we constrain the timing and amplitude of slip-rate fluctuations that occurred on three sub-parallel active normal faults in central Italy over a time period of 20-30 kyrs, using *in situ* ^{36}Cl cosmogenic dating of fault scarps. We identify five periods of rapid slip that lasted a few millennia separated by periods of time of up to 10 millennia with slow or no slip. We show a systematic migration of the location of rapid slip pulses across the strike of the three faults that occurred in two waves from SW to NE. We show that this migration of rapid slip can be replicated by a model where differential stress changes on shear-zones underlying the faults produce strain-rate changes, implying that this is the mechanism that produces the slip-rate fluctuations and temporal earthquake clustering. We show that the pattern of differential stress change is related to the fault geometry in terms of distance and azimuth from the slipping structure. This in turn implies that strain-rate and viscosity fluctuations for studies of continental rheology, and slip-rates for seismic hazard purposes are to an extent predictable given knowledge of the fault system geometry and the implied stress transfer function.

Estimating the long-term slip rate of active normal faults: The case of the Paganica Fault (Central Apennines, Italy)

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The footwall of the surface rupturing Paganica normal fault, the source of the 2009 L'Aquila earthquake (Mw 6.1) in Central Italy, was investigated using integrated geological and geomorphological approaches. The aim was to constrain the active tectonics by studying the Raiale River that orthogonally crosscuts the fault trace, where it provides a useful geomorphological marker of long-term fluvial incision and footwall uplift. Using morphostratigraphy and paleomagnetic analysis, the Plio–Pleistocene morphotectonic evolution of the area was reconstructed. Starting from the Late Early Pleistocene–Middle Pleistocene, fluvial dissection was mainly due to marked river downcutting triggered by significant activity of the Paganica Fault, which caused progressive base-level lowering. The Raiale River downcutting formed five Middle-Late Pleistocene fluvial terraces that, along with absolute Optically Stimulated Luminescence (OSL) dating, allowed the identification of paleolongitudinal profiles with a diverging downstream configuration. Terrace dating yielded a minimum incision rate of 0.25 ± 0.02 mm/a, which only partially compensates the footwall uplift and can thus be considered as a minimum value for the Paganica Fault throw rate, which could reach up to ~0.45 mm/a. In parallel, using terrestrial cosmogenic nuclides, a denudation rate of 0.02–0.04 mm/a was measured on the summit of the footwall block. This denudation is in keeping with the drainage incision, suggesting a non-steady state for the fault footwall topography and dominance of relief growth. Last, the analysis of the modern Raiale River longitudinal profile denoted an ungraded status, with two main knickzones that we interpret as transient forms due to tectonic perturbations, likely triggered by activity of the Paganica Fault during the end of Early Pleistocene and the Late Pleistocene. Considering the 2009 L'Aquila earthquake coseismic rupture, we observe that the younger transience on the Raiale River longitudinal profile, if it is of tectonic origin, could have only been produced by much larger seismic events (i.e., Mw > 6.5) than those documented in the area by paleoseismological investigations. The collective results confirmed that conditions of dynamic equilibrium are often not met in the Central Apennines and that the persistence of transient perturbations induced by tectonics should be accounted for.

Slip history of the Vallo di Diano, Auletta and San Gregorio Magno faults (Southern Apennines, Italy) constrained using cosmogenic 36Cl concentrations

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The 36-chlorine dating approach can recover slip histories from normal faults, providing information on slip-rate fluctuations produced by earthquake clustering over millennial timescales. It has been suggested that fluctuations in slip-rates are linked to fault/shear zone interactions. Specifically, for multiple parallel faults, clusters of surface faulting earthquakes have been shown to switch across strike between faults to maintain the regional strain-rate. However, for some fault systems faults are predominantly arranged along-strike and their behaviour has received less attention from 36-chlorine studies. Thus, it is not presently known whether normal fault systems with faults arranged along strike versus across strike behave in a similar manner over millennial timescales with regard to earthquake recurrence and clustering. We obtained 36-chlorine results for three faults located along strike in the Southern Apennines (Italy), one of the most seismically active areas in Italy (e.g., 1857, Mw 7.1, in the Val d'Agri and 1980, Mw 6.9, Irpinia earthquakes). The fault system is characterised by either a small number of faults across strike or a single fault accommodating all the across strike strain. Results show that the three faults (Vallo di Diano, San Gregorio Magno and Auletta faults) were active in the Holocene, with each fault exhibiting alternating periods of rapid and less rapid slip, thus accommodating the regional tectonic extension at different times. The faults are <30 km in length yet periods of rapid slip lasting a few millennia exhibit slip of up to 4-5 metres, implying the existence of temporal clusters of surface faulting earthquakes. In particular, the Auletta and Vallo di Diano faults show out-of-phase activity, so that when one fault experiences rapid slip, the other is in a state of quiescence. We discuss the results in terms of their implications for tectonic processes and seismic hazard.

Studying slow-to-moderate faults: New paleoseismic data of an unexplored branch of the Alhama de Murcia Fault (SE Spain)

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The Alhama de Murcia Fault (AMF) is one of the main seismogenic faults in the Eastern Betic Shear Zone (EBSZ). In the segment between Lorca and Totana, the fault is composed of five main branches that are considered to join at depth and, therefore, have their own contribution in terms of the seismic history and the slip rate of the main fault. A previous study constrained most of the activity of the fault in this sector by carrying out a paleoseismic analysis in four of these branches, leaving pending the analysis in one of them. This work focuses on the unexplored branch (N2a-AMF) to analyse its seismic potential and to refine the previously estimated paleoseismic parameters of the AMF in the area (El Saltador-La Hoya). We conducted a detailed geomorphological study to accurately map the N2a-AMF and to select a suitable location for the excavation of a paleoseismic trench. We also refined the mapping of N2b-AMF, which has been previously analysed, to better understand the relationship between both branches and the push-up they bound. In the new trench, we identified two different deformation planes (interpreted as fault propagation folds), which would have generated a minimum of 87±4 cm of joint vertical offset. A minimum of three morphogenetic events have been interpreted, providing robust evidence of recurrent deformation in Upper Pleistocene sediments, which implies that N2a-AMF has had activity at least during that period (dating is in course). According to correlation with regional dated units, these events would have taken place in the estimated time interval between 82,4 ka and 39,2 ka, presenting a minimum recurrence of 14,4 kyr. Taking into account the measured vertical offset of 87±4 cm, the minimum vertical slip rate for the last 82.4 ka would have been between 0.010 and 0.011 mm/year. In this work, we present the preliminary results of our ongoing research.

Paleoseismic recurrences obtained from intermittent geological records: New and Revisited trenching sites along the central Alhama de Murcia fault (SE Iberia)

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Inter-event time between morphogenetic earthquakes is one of the key parameters used in seismic hazard models and is, in most cases directly obtained from geological observations. Here, we analyze the paleo-earthquake sequence recorded at three nearby sites along the central part of the Alhama de Murcia fault (SE Iberia) by reviewing previously published data and by integrating new results. We discuss the definition of the rupturing events, correlating events among 9 different trenches from three sites, identifying new events previously undetected. Incorporation of new age results and a critical review of the existing chronological data is conducted to build up an improved earthquake chronology for the last 80 ka. Stratigraphical statistical age models obtained through OxCal tool leads to refined earthquake chronologies as compared to previous publications, reducing the uncertainties up to 39%. The integration of paleoseismological data from different trenches is shown crucial to build a more robust chronological model, even when the data from individual trenches is poorly dated or represent a discontinuous record. We discus some examples of published earthquakes chronologies inferred from intermittent versus continuous geological records highlighting the limitations and future perspectives of the use of paleochronologies for seismic hazard purposes.

Clustered activity of Intraplate Faults – relation to the seismic cycle? The silent and slow active faults of Germany: results from paleoseismological trenching

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Silent and slow faults in Stable Continental Regions (SCR) or active intraplate regions represent one of the most intriguing problems in active tectonic and fault hazard studies, like in Central Europe. The term “silent faults” is used very variable, “silent” refering either to seismic activity, absence of seismogenic faulting (but possibly creep) or to the scarce geomorphic and geologic visibility of faults. Slow active faults are generally characterized by slip-rates ≤ 0.1 mm/yr, with limited potential to produce topographic expressions in humid/moderate climate or even changing climates, i.e. out of the glacial periods in the Late Pleistocene. The slip-rate of a fault is a fundamental parameter that governs earthquake occurrence and seismic hazard in an area. Due to their long recurrence intervals of partly more than 10 kyrs, earthquakes on low slip-rate faults are often absent from the historical catalogues and the standard seismic hazard assessment processes, but are still visible in the landscape. Some faults show marked linear scarps and topographic steps, as revealed by high resolution DEMs and field surveys. The preservation of tiny scarps in agricultural areas is enigmatic: the process(es) of preserving a c. 50 cm high, single event scarp for 10^3-10^4 years is completely unclear.

We present new fault data from several SCR regions in Germany, the Lower and Upper Rhine Grabens, based on seismological, geophysical and trenching investigations. In general, Holocene surface rupturing events are very rare and their recurrence intervals are large, at around 10^3-10^4 years. Associated slip rates are below 0.1 mm/yr. Recurring paleo-earthquakes are recorded in surficial deposits, as shown in our trenches in the Rhine Grabens, along with secondary earthquake effects. In addition, some normal faults in the Lower Rhine Graben show evidence for the “Clustering and Quiescence” earthquake occurrence, which may explain the longevity of the scarps, and contrast the “One Shot” hypothesis stated for SCR faults. Furthermore, classical concepts like “cyclic earthquake behaviour” or “characteristic earthquakes” are not applicable for SCR faults. This suggest a major influence of the GIA (glacial isostatic adjustment) on the regional stress field in intraplate regions and fault activity.

Quaternary activity and seismogenic potential of intraplate strike-slip faults: Insights from the South Eastern Korean Peninsula

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Moderate to large crustal earthquakes (M>6-7) with possible surface deformation have been reported within intraplate tectonic settings, far from the plate boundary, but the historical record for those regions are too short to estimate the characteristics of the earthquake, recurrence interval, slip rate, and their seismogenic potential. Several damaging earthquakes have occurred in areas having null historical seismicity and very low to moderate slip rates such as the 2001 Bhuj Earthquake in India, the 2008 Wenchuan earthquake in China, the 2016 Peterman earthquake in Australia, and the 2020 Sparta earthquake USA. Paleoseismic studies are crucial for these regions, especially areas without historical earthquakes associated with surface rupture towards having a more realistic seismic hazard assessment. The earthquakes within the intraplate region are mostly distributed along several faults. But most of the paleoseismic studies are confined to active faults with well-preserved morphological expressions. However, our knowledge of strong earthquakes appears to be incomplete for active faults sitting within large fault systems in low slip and low to moderate seismicity areas. Given the lack of such studies within the Korean Peninsula, we have considered the one active fault sitting between the Yangsan-Ulsan Fault System (YUFS) for detailed active fault mapping and paleoseismic investigations. The fault was named Chungundong fault as per the locality. The detailed paleoseismic studies demonstrate the fault has experienced several surface rupturing earthquakes since the Late Pleistocene to the Holocene time with the most recent earthquake around ~4 k.y. With the last event occurring ~4 k.y. ago, the fault appears to be ripe for another large earthquake (moment magnitude, M_w 6-6.5 considering the length of the fault). These results emphasize the potential danger of intraplate continental faults, particularly those sitting close to the urban centers.

Paleo-faulting events of the slip-partitioned Idenokuchi fault that ruptured during the 2016 Kumamoto earthquake sequence, Japan

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The mainshock (Mw 7.0) of the 2016 Kumamoto earthquake sequence occurred on 16 April 2016 (UTC+9), and a ~30-km-long surface rupture appeared along the Futagawa fault and the northern Hinagu fault in central Kyushu, Japan. For this earthquake, InSAR confirmed numerous surface ruptures widely distributed far from the main fault (Fujiwara et al., 2016). Recent advances in remote sensing technology have revealed such complex and numerous surface ruptures (e.g., 2019 Ridgecrest earthquake; Milliner and Donnellan, 2020; Xu et al., 2020). Therefore, in our research group, we have conducted paleoseismic trench surveys on the surface ruptures away from the Futagawa fault (This study; Ishimura et al., 2021) and main surface rupture traces (Ishimura et al., 2022) for discussing the simultaneity between the primary Futagawa fault and secondary faults in the past events.

In this presentation, we present the result of a paleoseismic trench survey at the Idenokuchi fault, which showed normal faulting in the 2016 event and was pointed out that the slip partition occurred in the 2016 event (Toda et al., 2016). The study site is Komori Ranch, ~1.5 km south of the Futagawa fault. We excavated the trench (13 m long, 5 m wide, and 3.5 m deep) at the 30–50-cm south-up surface rupture. Based on radiocarbon dating and tephra analysis, paleo-faulting records for about 15,000 years have been continuously preserved in the trench. A maximum of 8 and at least 4 events (including the 2016 event) were interpreted from the trench walls. In particular, the activity after the K-Ah tephra (7.3 ka) is consistent with the paleo-seismic history of the primary Futagawa and secondary Miyaji faults, and it is estimated that similar activity has occurred at least four times recently. From this, it can be said that the appearance of many surface ruptures in the 2016 Kumamoto earthquake sequence was not a coincidence but an inevitable event.

Session 5:
Multidisciplinary hazard and risk study on active coastal and insular volcanoes

From space to seafloor data, from fieldwork to numerical modelling: an integrated approach to understanding the complex phenomena of tsunamigenic volcanic flows

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Tsunamis generated by landslides and pyroclastic density currents in volcanic environments are a serious but often underestimated threat. They are complex, cascading phenomena which can be extremely disruptive when occurring at high magnitudes . Fortunately, these major events have a relatively low frequency which leads to a scarcity of data and limited understanding.

Because of their complexity and the multiple hazards involved, they require data from different sources. Data from remote sensing and geophysical networks are needed to continuously monitor the volcanic activity and slope stability together with regular field, areal and marine surveys to assess the everchanging morphology which distinguishes active volcanic environment. At the same time, accurate characterisation of past events is needed to be able, through their back analysis, to improve the modelling of tsunamigenic flows from a hazard assessment perspective.

In this framework, we have studied the 3rd of July 2019 events at Stromboli Volcano, Italy. Stromboli is one of the most active volcanoes in the world, many tsunamigenic landslides (sub-aerial and/or submarine) have occured and a tsunami wave was recorded associated with the July 2019 eruption. This eruption was well documented by the existing dense monitoring network and also with amateur videos and the geomorphological changes were well assessed by pre and post field, satellite and bathymetric data. This allowed us to characterise in detail the event and its timeline. Thanks to the back analysis of the events with the two fluids version of VolcFlow, a continuum mechanics model developed by the Laboratoire Magmas et Volcans (France), we were able to assess the causes of the tsunami and the 'best fit' rheology of the phenomena which generated it. We then carried out a parametrical study to identify the main factors of influence in determining the height and reach of the wave.

In conclusion, thanks to the interdisciplinary and integrated approach used in this study and the international team involved, we were able to obtain a comprehensive and accurate picture of different types of tsunamigenic flows, which ultimately leads to a better understanding of their impact and increased awareness of the risk they pose.

Rapid geomorphological changes in active volcanic settings: the Stromboli case history

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Active volcanoes are highly dynamic geomorphological systems, responsive to both gravitational processes and magmatic/tectonic activity. The former are responsible for the transfer of material from steeper slopes to areas with lower gradients, whereas endogenous forcing can generate accumulation of erupted products or alternatively it can trigger moderate to large-scale mass-wasting. In order to quantify the geomorphological processes that occur in active insular volcanoes, integrated topographic and bathymetric surveys and remote sensing techniques are fundamental tools. This comprehensive approach has been applied to Stromboli volcano, where multi-platform and multi-temporal data were collected in the last decade on the Sciara del Fuoco, the steep and unstable, NW submarine-subaerial slope of the volcano.

Topographic data include multi-temporal digital elevation models (DEMs) by Light Detection and Ranging (LiDAR) data and by photogrammetry using images collected by PLÉIADES satellites and Unmanned Aerial Vehicle (UAV). Topographic change detection was also supported by data from high-spatial-resolution (HSR) optical imagery (QUICKBIRD and PLÉIADES), and COSMO-SkyMed Synthetic Aperture Radar backscattering images. Offshore data includes repeated multibeam (MBES) bathymetries and Side Scan Sonar (SSS) backscatter of the submarine flank.

The results show that fluctuations in “ordinary” volcanic activity lead to the accumulation (for higher frequency of explosions) of the erupted material from the crater area on the Sciara del Fuoco slope. In periods of lower frequency of explosions, instead, prevalent reworking by subaerial weathering and by marine processes is observed. The “anomalously intense” eruptive phases, which consists of lava flows emission and/or high-intensity explosive activity with generation of pyroclastic density currents (PDCs), lead to significant accumulation and erosion of the Sciara del Fuoco slope in a very short time. This has three main implications: 1) the alternation of brecciated lava and heterogenous volcaniclastic deposits, with reduced lateral continuity, may play a role in the Sciara del Fuoco slope stability; 2) lava flows or PDCs entering the sea have erosive potential also on the seafloor, with implications in modeling both PDCs and tsunamis; 3) the rapid geomorphological dynamics of active volcanoes require multi-temporal surveys repeated over short time intervals, including a multi-platform approach, to capture rapid changes.

How frequent are major geohazard events in the central Azores volcanic islands? Insights into landslide mapping and dated volcaniclastic turbidites

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Eruptions, submarine landslides and landslide-induced tsunamis can potentially affect communities badly, so information on their frequencies and magnitudes is urgently needed. We outline work on the central Azores islands, where multibeam bathymetric data have revealed abundant submarine landslide valleys in the uppermost submarine slopes of the islands. Those valleys range in size, with the largest potentially capable of generating tsunamis of >1 m height at source and therefore of concern. The islands are surrounded by flat basins, which likely capture the products of submarine landslides and volcanic eruptions, and thus allow them to be dated. Sediment cores from those basins contain abundant volcaniclastic (VC) turbidites. Of those, only one-third are likely generated by submarine landslides (from evidence including shelf carbonates). The contrast in abundance with the landslide valleys is intriguing. To investigate this further, age-depth models built from the hemipelagic intervals and tephra-stratigraphic correlations are used to date individual VC turbidites. Volumes of the VC turbidites are calculated by multiplying basin areas with bed thickness, also accounting for various distal thinning rates and input directions. Those volumes were used to estimate sediment fluxes. Fluxes of hemipelagic and landslide-generated sediments turn out to be much smaller than fluxes of sediment created on the shelves by erosion and biogenic production. Furthermore, the estimated volumes of turbidite in the basins are commonly larger than 10^6
m^3, only comparable with the largest submarine landslide valleys (i.e., 10^6-10^7 m^3) on the adjacent slopes. These results imply that turbidites in the cores originated only from the largest events; sedimentary flows produced by small landslides instead mostly die out and deposit on the slopes without reaching the basin floors or were too small in the basins to be recorded (e.g., because of bioturbation). The recurrence intervals of eruptions and landslides suggested by age-depth modelling (both ~kyr), therefore, only represent the large events. Our finding highlights the need for sampling the slopes of the islands as well as the basins to recover the spectrum of turbidites more completely.

Geological monitoring of the lava flow on the shelf and slope of La Palma Island during de Tajogaite eruption, 2021

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The Tajogaite volcanic eruption took place on the southwestern flank of La Palma Island between September 19th and December 13th, 2021. An oceanographic study of the area was carried out to control the effects of the submarine lava flow on the seabed, developed in three-time windows during the eruption. Changes in morphology, extent, and thickness, have been studied by combining pre and successive post-bathymetric datasets, with 1m of spatial resolution, using an MB710 multibeam echosounder. To characterize the lava flow facies and different substrate types it has been used an ROV-Liropus 2000. The first bathymetric survey was carried out in the most probable arrival zone of lava flow to the sea to establish the pre-eruption characteristics of the insular shelf and slope where several gullies and their head-scarps were located.

On September 28th, the lava flow arrived at the ocean forming two lava deltas: the northern and smaller one located to the south of the Tazacorte harbor, and the southern and main one attached to the north side of the lava delta generated during the 1949's eruption. The new volcanic materials have been identified at least to a depth of 360 m and approximately 1.2 km from the initial shoreline, occupying an estimated submarine area of 35 ha. The northern lava delta has been emplaced on the inner shelf but in the southern one, the subaerial part reaches the old shelf edge where they have rested on a rocky platform and the submarine lava flow has been channeled into shelf depressions and submarine gullies that intersect the shelf border and the upper slope, totally transforming the relief. Lava flows advanced along the seabed both as "aa" and block flows in the proximal area, also forming megapillows of different sizes on the upper slope.

The monitoring of this eruption allowed studying, in real-time, the arrival of a lava flow to the sea and the associated modification of the coast and seabed. Results provide additional information on the development of the eruptive episode on La Palma Island providing a more complete picture of the functioning of the volcanic system.

Post-eruptive coastal erosion of volcanic oceanic islands formed by historical eruptions

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Coastlines of island volcanoes are dynamic due to their exposure to ocean waves and consequently hazardous from cliff collapses. Historically erupted island volcanoes are useful for such studies as they offer the opportunity to observe how their coasts have evolved throughout their lifetimes. Commonly their young coasts are eroded rapidly as their cliffs are not protected by wave attenuation due to a lack of a littoral platform. We have derived coastline positions from satellite images, survey maps and aerial photos for Capelinhos (Azores, erupted 1958), Surtsey (Iceland, 1967), Sholand (southern Red Sea, 2011), Hunga Tonga Hunga Ha'apai (Tonga, 2015) and La Palma (Canaries, 2021). Post-eruptive coastline erosion rates vary between them as they are subject to different wave regimes. However, results show that in all cases coastal erosion rates were rapid in the early stages following the eruptions but then declined gradually with time. Marine geophysical data collected around the Capelinhos coast reveal how erosion has left a littoral platform. Attenuation of waves crossing such a platform could contribute to the slowing of erosion rates, but modelling suggests that attenuation cannot explain the majority of that change. We suggest that the common slowing of erosion rates is probably due to the outer erupted materials of the cones typically being unconsolidated and erodible, while deeper materials are more consolidated and/or lithified. Consequently, although cliff collapses can become larger with time as cones are dissected by wave erosion, the frequency of cliff collapses declines.

Comparison of seismic and acoustic signals coming from the submarine hydrothermal system of Panarea Island (Aeolian Archipelago, Southeastern Tyrrhenian Sea)

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The observation and analysis of seismic and passive acoustic signals represent an effective method for both short- and long-term monitoring of submarine hydrothermal activity in volcanic areas. In this context, the aim of this work is to present preliminary results of the analysis and comparison of seismic and acoustic signals recorded at the beginning of October 2022, during an experiment focused on short-term monitoring of the Panarea submarine hydrothermal system in the eastern sector of the Aeolian Arc (Southeastern Tyrrhenian Sea). This shallow submarine hydrothermal system, the most active among the hydrothermal systems of the Aeolian Archipelago, has given rise to a strong gas emission in 2002-2003. For the first time, hydrothermal activity is investigated by coupling acoustic and seismic data in order to expand the knowledge of the system behavior. Seismic data collection was performed by using a wideband (120 s - 500 Hz) 3-component Ocean Bottom Seismometer (OBS), while the acoustic data were acquired with a passive hydrophone [1-50000] Hz. Both instruments were integrated into a fixed multidisciplinary underwater observatory which provided power supply and internet connection. The application of various time-frequency analysis methods permitted to recognize different energetic frequency peaks, diverging from the background ambient noise, which characterize both seismic and acoustic signatures. These frequency peaks can be correlated to different source mechanisms, related to fluid dynamics along the discharging cracks. Both the instruments recorded energetic peaks sourced by spasmodic tremor, spanning between 2-30 Hz frequency range. Harmonic and narrow band peaks, centered respectively at 50 Hz and 150 Hz, likely sourced by the discharging dynamic of the brine that seeps out just a few meters away from the instruments were detected as well. Finally, we have performed a directionality analysis of the seismic signals computing the Fourier amplitude spectra as a function of azimuth in the horizontal plane, and this has allowed us to identify and confirm the location of sources in the submarine hydrothermal system of Panarea Island. Furthermore, this study improved the current state of our understanding of the processes related to fluid dynamics and to suggest practical methods of monitoring in extreme environments.

Morpho-acoustic characterization of the submerged portion of La Fossa Caldera (Vulcano Island, Tyrrhenian Sea, Italy) through the integration of multi-temporal multibeam bathymetric data and video footages.

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The flanks of active insular volcanoes are highly dynamic environments characterized by fast morphological evolution, which may create hazards for local coastal communities. Vulcano Island (part of the Aeolian archipelago, southern Tyrrhenian Sea) is the top of an active stratovolcano, whose last eruption occurred in 1888-1890. The island is characterized by two calderas and part of the younger multi-stage La Fossa caldera is below sea level. The submerged part extends down to depths of 300 m and is bounded by two very steep submarine scarps, with slope gradients up to 80°. This submerged area is characterized by a series of primary volcanic features carved by a network of small gullies that often arrive up to the shallow-water setting, mining the stability of the NE flank of La Fossa cone, as testified by the development of a small tsunamigenic subaerial landslide in 1988. In addition, the caldera has historically been site of intense hydrothermal activity, still ongoing as testified by the subaerial and submarine degassing crisis started in December 2021.

In this work, we present an integrated analysis of high-resolution multi-temporal bathymetric data collected between 2005 and 2022, backscatter data and video footages acquired both from Remotely Operated Vehicle (June 2022) and research submersible JAGO (February 2020). The integrated analysis allows a morphological characterization of the main volcanic and erosive-depositional features characterizing the submerged La Fossa Caldera as well as of the main features related to the degassing activity occurring in very shallow-water.

Session 6: Recent advances in understanding the Quaternary geomorphological evolution of continental margins

Dynamic landscapes in active coastal and submarine volcanoes in the south Aegean Volcanic Arc: Santorini and other volcanoes

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Greece is a rare physical laboratory since it is one of the most seismically and volcanically active areas in Europe. This is associated with the Hellenic subducting system and the regional tectonics that produced an island arc in the late Eocene. The latter has migrated from the N to the S and currently lies in between neotectonic and active tectonic grabens in the Aegean microplate. The activity in the Hellenic volcanic arc initiated on its western margin in the Late Pliocene while the rest of it formed Quaternary centres.

Here we present the most well-known and well-studied onshore and offshore features found on the volcanic islets. The arc comprised several volcanic edifices, with the most intriguing geomorphological agents being the Methana, Milos, Santorini and Nisyros volcanic groups. In particular, we unfold the geomorphological evolution of the arc from the W to the E and present its gradual transition from dome landforms to craters and collapsed caldera landscapes.

Our analyses have shown that although all the volcanic centres share a similar geological evolution as part of the Aegean microplate, their geomorphological fingerprint is highly heterogeneous both along the arc and in an island scale. The volcanic activity in all centres is present onshore and offshore hosting effusive and explosive landforms such as cones, domes, craters and shallow submarine hydrothermal vent fields, respectively. The Christiana-Santorini-Kolumbo volcanic group remains a key agent of geomorphological heterogeneity combining rough landscapes in its interior (e.g., calderas and craters) surrounded by smooth surfaces (erosional features, sculptured ignimbrites) on the outskirts. All the reported geomorphological features thus far demonstrate still a balanced but dynamic interaction between the volcanic and terrigenous environment. The latter is related to dynamic interactions between the volcanic activity and the erosional processes that sculpture the terrestrial and submarine topography along the arc.

Tectonically controlled landforms of the Hellenic Trench and the Aegean back-arc

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The Hellenic Trench and the Aegean back-arc display a large variety of seafloor landforms that reflect the complexity of Quaternary tectonics and kinematics. We use the 100 m DTM (EMODnet Bathymetry) and swath bathymetry to describe the geomorphological features and highlight their relationship with the active geological processes.

The Hellenic Trench contains three distinct sectors and encompasses a series of deep troughs, steep slopes, canyons, seamounts:

The northwestern sector marks the 3000 m high escarpment of the dextral Kephallinia transform fault-zone. The Kephallinia Valley has developed along the Kephallinia Fault and is the deeper part of a roughly 200 km long valley that starts from Otranto Strait.

The western sector, the Ionian Trench, extends from the Ionian Islands to the south of Gavdos Island, is oriented roughly perpendicular to the convergence direction and is characterized by compressional and lateral escape tectonics. It features small, isolated, deep (>5000 m) basins, separated by shallower ridges and includes the 5200 m Oinousses Deep.

The eastern sector is characterized by sinistral oblique compression and is delineated by three striking features: the Ptolemy Trench south of Crete and the Pliny and the Strabo Trenches that terminate in Rhodes Basin (4000m). Ptolemy (2500-3700 m) and Pliny (3700-4500 m) Trenches have developed within the Aegean crust. Strabo Trench (3000-3500 m) marks the boundary between the Aegean crust and the Mediterranean Ridge.

The Aegean Sea marks the SSW-wards extending back-arc between the retreating Hellenic subduction and the western termination of the North Anatolian Fault. The morphological puzzle includes: (i) a large number of rhomboid, elliptical or spindle shaped, up to 2500 m deep, isolated basins, (ii) up to > 50% steep, faulted slopes striking NE-SW to ENE-WSW and in NW-SE to WNW-ESE, (iii) seamounts, ridges and islands of tectonic and volcanic origin, (iv) canyons and gullies incising the steep slopes or separating structural lows. Normal, oblique and strike-slip faults control subsidence of the Quaternary basins, the formation of the shallow ridges and mounts, the development of steep slopes in between them and the incision of narrow and deep valleys.

Quaternary basin formation and deformation in the Aegean back-arc area

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This work is part of a long-term research project on the geodynamic evolution of the Aegean Sea, in Greece. It includes the reinterpretation of old, analog seismic profiles and recent seismic and swath bathymetry data processing.

The deforming Aegean crust flows towards SW between two major boundaries, the dextral North Anatolian Fault and the Pliny and Strabo Fault Zones. The kinematic model with arc-parallel zones of extension since the Early Pliocene can hardly explain the structural and morphological configuration that evolved during the Quaternary. Recent studies have shown that isolated basins and ridges associated mainly with NW-SE and NE-SW oblique to strike-slip faults and roughly W-E normal faults characterize the Aegean morphology. Large arcuate extensional basins are not observed in the present Aegean morphology.

A two-stage structural evolution of the South Aegean is proposed here: the wide, arc-parallel, Pliocene basins evolved since the Early Quaternary into a more complex structure with multiple basins separated by shallow ridges. The orientation of the individual subsiding and uplifting blocks, predominantly in NE-SW to ENE-WSW and secondarily in NW-SE to WNW- ESE directions, coincides with the strike of the major faults that control the Aegean deformation. Major unconformities have been mapped within the Plio-Quaternary sedimentary sequence of the Aegean basins and are related to the geodynamic, structural and morphological re-arrangement. These unconformities mark the deactivation or re-orientation of the older major, basin-bounding faults and the initiation and propagation of new ones.

The reliable dating of this tectonic re-arrangement is not yet possible. Chronological estimates derive from the interpretation of low sea level prograding sequences and the ODP drilling project in the Cretan Basin indicate an Early Quaternary approximate age for this tectonic change. The driving mechanism of this major change in the geodynamic regime of the Aegean back-arc in the Early Quaternary is not confirmed yet. However, the propagation of the North Anatolian Fault in the North Aegean may be a good candidate.

Variations in the Provenance of Yangtze Delta over the Holocene

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The Yangtze Delta, located at the east Asia continental margin, is one of the mega deltas on the Earth system. As a typical tidal dominated delta, it has been formed and shaped under the influences of both fluvial and marine dynamics since the middle Holocene (~7-8 ka). Detrital records preserved in the stratigraphy of the Yangtze Delta system provide abundant information of Asia climate change and land-sea evolution over the Holocene. Deltas nowadays worldwide share a fate of erosion, drowning or shrinking due to global climate change and intense human interventions. Potential risk predictions and long-term sustainable management and protection of the coastal delta systems require a detailed understanding of the sedimentation process and forcing mechanism in shaping the deltas over the past thousands of years. Sediment supply for the Yangtze Delta and its dynamic response to climate change have long been active research subjects. In this study, we investigated three sedimentary cores across the Yangtze Delta, for which the chronology frames have been well established. We used an end-member modelling approach on the bulk grain-size distribution datasets to characterise sediment sub-components and their relative contributions within the three cores. We further provided the detrital zircon U-Pb geochronology for different sedimentary facies of the three cores and compared them with the integrated large-N zircon U-Pb age dataset of the Yangtze River's upper and middle basins. We aim to offer a refined detrital provenance model and quantitative analysis on the sediment supply to the Yangtze Delta through the Holocene. Our data indicate a temporal variation in the provenance of the Yangtze Delta during the Holocene and recognise possible sediment supply from the marine source since the last 1ka.

Reconstruction of the Laurentide Ice Sheet based on a geomorphological analysis of glacial landforms on the Labrador Shelf

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The eastern Canadian margin, especially the Labrador Shelf, is one of the key areas to study climate variations from the Cenozoic to the present. During past glaciations, vast areas of Northern North America were covered by thick ice sheets, such as the Laurentide Ice Sheet (LIS). In periods of melting, these ice sheets released significant amounts of freshwater into the North Atlantic and influenced the ocean circulation, particularly the Atlantic Meridional Overturning Circulation (AMOC). Open questions concerning the effect of global warming on the AMOC stimulate discussions and studies on the mechanisms responsible for the strength and heat flux of this ocean circulation. Since changes in the AMOC are mainly caused by natural climate fluctuations between glacials and interglacials, it is critical to examine the dynamic behavior of the LIS in detail. However, data on the dynamics of the LIS are mainly derived from sediment cores located far offshore in the Labrador Sea and information from the Labrador Shelf is limited to Holocene sequences. Therefore, the aim of this study is to analyse the geomorphological evolution of the Labrador Shelf in order to draw conclusions to the dynamics of the LIS. In particular, we update the knowledge of the extent of the LIS at its distal marine limit and provide constrains on the last ice sheet retreat based on state-of-the-art high-resolution geophysical data imaging from the Labrador Shelf. In 2015 and 2019, we carried out expeditions to the Labrador Sea to investigate the transverse troughs and intervening banks of the shelf by a combination of bathymetric mapping, sediment echosounding and sediment coring. We discovered glacial landforms like grounding-zone wedges and iceberg scours likely related to the last glaciation. Further, we carry out a geomorphological analysis of these landforms to reconstruct the Quaternary evolution of the shelf. In conclusion, we combine our results to a model of the dynamic behavior of the LIS, which can be used to infer possible processes that led to freshwater surges in the central Labrador Sea during the Pleistocene and early Holocene.

3D Mapping and Integrated Geospatial Data of the Molloy Hole (Arctic Ocean)

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Based marine geophysical data collected during the IT-Navy HIGH NORTH20 and HIGH NORTH21 campaigns, a 3D integrated mapping of a region between 78.5-81°N and 1-8°E, where the Molloy Hole is located (Fram Strait – Arctic Ocean), has been developed. The Molloy Hole is the deepest undersea feature of the Arctic Ocean and plays a structural key role in the ocean geodynamics in terms of new ocean seafloor and gravitative mass movement, sink or barrier to the dynamics of the water masses with confined sedimentary processes in the presence of melting ice, polar and Atlantic current. The ocean surface (water and ice), the water column and the seabed data, thanks to an integrated-multidisciplinary approach and harmonization techniques named 'imagery box', has been processed using MATLAB R2021b to obtain a high-resolution 3D model. In particular, the research activities collected water column, bathymetry and acoustic backscatter from multi-beam sonar surveys, CTD data, and sedimentary samples from box corers. The need for a visualization to aid in the comprehensive analysis of all elements of this imaginary box is the main reason behind this research. Consequently, it seeks to integrate in situ and remote sensing measurements in order to provide an integrated mapping of the study area as a one single product. In order to achieve this goal, it is essential to optimize the process by standardizing the file formats so that all data can converge into a complete 3D depiction of the elements that compose the ocean: sea surface, water column and seafloor. The unification of distinct geospatial data should be of great help to scientists when analysing their own 'imaginary boxes'. This mapping is an integrated data product starting from the raw data in order to create a unique processing tool, and to produce a complete and comprehensive depiction of the 3D marine environment. This 3D integrated mapping highlights the undersea features as the drivers of the dynamics of the Molloy Hole from the sea surface to the ocean bottom.

Submarine morphology of Pantelleria Island: interplay between volcanic and erosive-depositional processes modulated by sea-level fluctuations

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The study of submarine portions of insular and coastal volcanoes exponentially increased in the last decades through recent advances in seafloor imagery and seismic techniques that allow reconstructing the main volcanic, tectonic and erosive-depositional processes affecting the volcanic edifices. In this study, we analyse the detailed submarine morphology of Pantelleria, a large composite Quaternary volcano belonging to the magmatic district of the Sicily Channel (central Mediterranean Sea), located in a continental rift context.
The most recent eruption at Pantelleria was submarine and occurred in 1891, about 5 km NW of the northwestern coast of the island, producing floating basaltic lava balloons observed at the sea surface. The volcanic edifice is ~36 km long and ~15 km wide, encompassing a surface of approximately 300 km^2. Some …% of the volcano lies below sea level. The edifice is markedly elongated along the NW-SE direction and rises above the Pantelleria Basin between 700 (NW flank) and 1300 (SE) m water depth. The submarine volcanic flanks are characterized by different declivities and distribution of primary (volcanic) and erosive-depositional features. The former ones include volcanic cones, elongated ridges, lava flows, and outcrops. Slides scars, channels, gullies, insular shelf and infralittoral prograding wedges are recognized among the latter ones. Based on the integration of morpho-bathymetric analysis and available seismic reflection profiles, the aim of the paper is twofold: (i) to show the interplay between volcanic, tectonic and erosive-depositional processes, the latter ones also modulated by sea-level fluctuations, in shaping the submarine morphology of the Pantelleria volcano, (ii) to reconstruct the morpho-structural evolution of this edifice, providing new insights on vertical deformations occurred in the Late-Quaternary through the use of marine geomorphic markers.

Millennial-scale patterns of Mid-Late Holocene environmental evolution from the southern Adriatic shelf (Apulia, Italy) as revealed by multivariate data

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Due to the complex interplay between river plumes, storms and sea currents, a variety of morphologies and depositional environments commonly typifies shelves. With the aim of better understanding the lateral and vertical succession of shallow-marine facies and associated paleo-landscapes, we analysed the Mid-Late Holocene record of three cores (INV12-15; SI08-27 and COS01-16) retrieved from distinct bathymetric sectors of the Apulian shelf (Southern Adriatic Sea, Italy). Boreholes INV12-15 and SI08-27 are located within the Gulf of Manfredonia, south of the Gargano Promontory, at 15 m and 30 m water depth (wd) respectively, while COS01-16 was drilled at 76 m wd on the open shelf.

Framed into a robust chronological and seismic-stratigraphic framework, a multiproxy approach based on paleobiological (ostracods and benthic foraminifers) and geochemical data allowed us to recognize patterns of environmental evolution and changes in sediment transport pathways over millennial timescales. Under substantial highstand sea-level conditions, stratigraphic variations in meiofauna associations mainly reflect changes in organic-matter fluxes, oxygenation and hydrodynamic levels at the sea-bottom. On the other hand, vertical profiles of trace-metal distribution highlight changes in the relative contribution of Po-Apennine rivers (via the Western Adriatic Current) *versus* Apulian rivers, directly feeding the Manfredonia gulf.

Within the gulf, paleoenvironmental changes are in-phase with shifts in sediment source, testifying the close correspondence between facies patterns and the trajectories of fluvial inputs. Up to ~7000 cal. years BP, the gulf area hosted a shallow-marine environment subject to low-moderate organic-matter fluxes from the Apulian rivers. Afterwards, a fully river-influenced setting occurred, recording a positive trend in organic-matter enrichment under the progressive increase in Po-Apennine riverine input that marks the diachronic development of the Adriatic prodelta mud wedge into the gulf (~6000-2500 cal. years BP). On the open shelf (core COS01-16), the sea-bottom was steadily affected by Po-Apennine inputs that led to the vertical stacking of outer shelf muds (up to ~7000 years BP), progressively more enriched in degraded organic matter (~7000-6000 years BP), with distal prodelta muds (since 6000 years BP) on top.

Seafloor morphology and recent dynamics in the Scoglio Affrica (Northern Tyrrhenian Sea)

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Seabed gas emission phenomena in the Northern Tyrrhenian Sea have been detected using a high resolution swath bathymetry, while nature of seabed and water column were investigated with acoustic backscatter and geochemical data. Since 2017, the Scoglio Affrica islet has been surveyed and monitored after a transient event of gas and fluid emission from the seafloor that originated a geyser above the sea level. These transient phenomena occur very localized both in space and in extremely short time. The complexity of these kind of events requires an integrated monitoring system, which allows us to characterise the seafloor morphology and recent dynamics through a multidisciplinary research. The collected data provided the purpose for detecting new target of the seafloor recent dynamics and gas emissions, such as volcanic morphological features, mud volcanism, particular geochemical composition of water and sediment, as well as petrographic observation and grain size of the latter. This study allowed to obtain insight information on the temporal and spatial evolution of seafloor morphology related to gas emissions in the area of the Scoglio Affrica in order to create a map of the features and emission points referring to the recent dynamics in shallow water. At least four mud volcanic structures are located in this area with different seafloor evolutionary records, including sediment consolidation, fracturing and variation in morphology and depth of the sea bottom, likely related to the inflation/deflation of the mud volcanoes as well as to the wave action.

Quaternary geomorphological evolution related to continental slope and seamount instabilities of the Mallorca Channel (western Mediterranean)

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The geological study of the Ses Olives, Ausias March and Emile Baudot seamounts and adjacent areas located in the Mallorca Channel (Balearic Promontory, western Mediterranean) using multibeam bathymetry and backscatter data and high-resolution parametric profiles has allowed us to identify several morphological features of different scales associated to gravitational and erosive-related processes. Major morphological features characterized are slides, slide scars, mass-transport deposits (MTDs) as well as different gully-systems affecting seamounts flanks. Slide scars have been recognized at the top and flanks of the seamounts as well as at the adjacent areas in the central basin. They show diverse geometries that can be affected by scarp faults and pockmarks developing multiple steep scars with lengths of up to 15 km. MTDs are identified throughout the entire study area and present mostly elongated morphologies. They extend between 1 and 11 km from the scars, and locally present perpendicular trajectories between the different sedimentary bodies. They generate seafloor reliefs of more than 20 m and up to 50 ms thick in the seismic profiles, identifying stacks of, at least, three different episodes. In some cases, the movement of the displaced mass in the subsurface have produced a high deformation of the materials located above. Gullies are mostly located on the flanks of the Ausias March and Emile Baudot seamounts, as well as in the north central flank of Ses Olives. They have a rectilinear shapes, although with an irregular distribution, with orientations that vary from NW-SE to NE-SW for the Ausias March and Emile Baudot, respectively, and SO-NE in Ses Olives. They develop small slides and bedforms of turbiditic origin. The integrated analyses have allowed us to calculated that the area affected by sedimentary instabilities is around 10% of the study area (500 km^2) mainly related to tectonics and fluid expulsion processes. This study will offer new insights and understanding of the geological hazard scenario in this sector of the Balearic continental margin.

Geomorphology of the northern and southern continental margins of the Iberian Peninsula: Quaternary interplay of tectonics and sedimentation

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Geomorphic evolution of tectonically active continental margins is the result of the interplay of deformation and sedimentary structures. Iberian Peninsula, located in the present-day NW-SE convergent Eurasia-Africa plate boundary, is mainly deformed in the northern Cantabrian margin (NE Atlantic) and in the southern, both Alboran and Gulf of Vera margins (SW Mediterranean). These margins develop elongated highs and basins roughly parallel to the margins. Moreover, faults and volcanic structures affect the southern Iberia margin. All these deformation structures are responsible for the regional configuration and physiographic components of the margin, seafloor topography, as well as entry points of sediment and pathways of the alongslope (bottom currents) and downslope (mass-transport and gravity flows) sedimentary processes.

The deformation structures condition the distribution of deep-sea bottom currents and their sedimentary geomorphic impact is regionally variable during the Quaternary. Contourite features are dominant in the Alboran Sea to the extent that their distribution conditions the physiography. This significant action of bottom currents is linked to the semi-enclosed basin configuration that favours the confinement of the Mediterranean waters. Contrasting, in the Cantabrian and Aguilas open margins, bottom currents are topographically steered by the highs and form local contourite features. Deformation structures also influence the downslope sedimentary processes. Mass-transport and sediment gravity flow features are mostly shaping the Cantabrian and Gulf of Vera margins during the Quaternary. Their occurrence is related to the overstepping or tectonic tilting of the margins, shelf-indenting canyons and narrow shelves. Contrasting, those features are less extended in the Alboran Sea, where their formation is related to seismicity, overstepping of highs, fluid dynamics and turbidite systems. These results indicate that the regional tectonic style of deformations driven by the inherited crustal heterogeneities can be considered a main factor that determines the Quaternary geomorphic sedimentary processes. All these results indicate that the regional tectonic style of deformations driven by the inherited crustal heterogeneities can be considered a main factor that determines the Quaternary geomorphic sedimentary processes.

Bedform development along the shelf-incising Carchuna Canyon, northern Alboran Sea (western Mediterranean Sea)

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This study focusses on improving our understanding of bedform forming processes in shelf-incising submarine canyons, using the Carchuna Canyon as a case study. To achieve this aim, we used: (1) multibeam bathymetric data, (2) grain-size data, (3) sub-bottom acoustic profiles, and (4) Flow 3D Hydro to simulate flow conditions along the canyon.

The Carchuna Canyon is deeply incised in the shelf, and its head is located just 200 m off the coastline. The axial channel in the upper segment is covered by crescent-shaped bedforms (CSBs), with downcanyon evolution from fine sands into very coarse silts. Sets of CSBs also occur in the lower segment axial channel, where sediments change from very fine sands to distal coarse silts in levees. On the open slope east of the lower segment, two types of sediment bedforms have been identified: sediment waves with decreasing size downslope and two trains of N-S large scours.

Acoustically, three acoustic facies were identified in the sub-bottom profiles were determined in the lateral deposits. The lower facies exhibit undulating and discontinuous low to medium amplitude reflections with laterally variable thickness. The middle facies are characterized by a transparent acoustic response. The upper facies develop an undulating seafloor. Flow simulation suggest the highest average flow velocity along the canyon thalweg. Out of the valley, average velocities are higher on top of the bedforms crests, whereas the higher Froude number values occur in the lee side of bedforms.

The occurrence of CSBs in the axial channel point to down-canyon turbiditic flows along the channel, possibly conditioned by the extensive shelf incision of the canyon and its proximity to the coastline, which favour the capture of littoral sediment transport and the formation of gravity flows. The bedforms outside of the axial channel are linked to turbidity current spill over meander bends, resulting in the formation of net-depositional (sediment waves) or net-erosional cyclic steps (scours) due to repeated hydraulic jumps.

In the recent past, paleo-bathymetric steps possibly favoured the formation of sediment waves out of the valley. These bedforms exhibit an upslope asymmetrical migration pattern, suggesting lower energy flow through time.

Are present-day infralittoral prograding wedges (IPWs) reliable geomorphological indicators of current sea level? A challenge to their use from the Campania Region IPWs Database (CRID).

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A census of 83 Infralittoral Prograding Wedges (IPWs) was carried out in the Central-Eastern Tyrrhenian Sea, to learn more about their morpho-bathymetric variability and test their reliability as geomorphological indicators of current sea level. A dataset reporting for each IPW the main morphometric indices (distance from the coast, depth, foreset and tospet slope angle, length, direction), the ground elevation (GEB) in the backshore and more, the effective fetch (EF) and the maximum significant height of the storm waves (Hs) to which they might be exposed, was then implemented (Campania Region IPW dataset, CRID). GEB, EF and Hs are environmental descriptors related to the external forcings acting on each IPW and accounted for by the energy of the relief and the local sea state. The multi-regression analysis among indices highlighted a significant correlation of IPWs depth with EF and Hs and a moderate correlation with GEB. The Principal Component Analysis (PCA) evidenced two clusters of indices, where depth and distance appear as being governed by sea state forcing and foreset and topset slope angles by the energy of relief in the backshore, respectively. The outcomes emerged from the observational law on present-day IPWs were then applied to relict IPWs, sited on the continental shelf and at the shelf margin, with the aim of establishing their original depth of formation, and test their reliability as proxies for past sea levels. The original depth of relict IPWs was roughly established by adopting a simplified equation that relates the depth to the EF. This procedure provides an analytical method for gauging the original depth of relict IPWs in the eastern Tyrrhenian Sea by using an easily computable geographical index.

In conclusion, this study explores the relationship between the depth of present-day IPWs and sea storm wave climate at a regional scale and provides clues for using relict IPWs as geomorphological proxies of past sea level stands. A wider dataset recording a larger number of IPWs indices would consent to extend the observational law on present-day IPWs to a Mediterranean scale and strengthen the applicability of the method to a spatially-broader set of relict IPWs.

Controlling factors on the geomorphology of mixed siliciclastic-carbonate margins: A case study from the Quaternary Belize margin

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Along mixed siliciclastic-carbonate margins, sediment dispersal to adjacent basins is not necessarily primarily controlled by sea-level variations and terrestrial sediment supply, but also by the cohabitation of the reef and siliciclastic systems. Although both systems are well studied individually, the co-evolution of siliciclastic and carbonate systems and their mutual impact on continental-margin geomorphology is still poorly understood, which is reflected in the paucity of numerical and conceptual models of mixed siliciclastic-carbonate margins. The aim of this research is to better understand the mutual influences on the geomorphological evolution of mixed siliciclastic-carbonate margins of (1) the siliciclastic river system progradation onto emerged shelves, including its deltas reworked along coastal beach ridges and slope fans, and (2) the reef establishment, growth, and exposure through the sea-level cycle.

For this purpose, the co-evolution of the late Quaternary mixed siliciclastic-carbonate English Caye Channel (ECC) system was studied along the Central Belize margin. The ECC system comprises (1) a well-developed river drainage system of infilled incised valleys, parallel and landward of the coralgal barrier reef, merging into (2) the ECC itself, a km-wide partially filled incised valley crossing the barrier reef, and (3) at its mouth, on the seaboard of the barrier reef, a well-developed shelf-edge delta and linked slope fan. We investigated: 1) the role of pre-existing reef-created seafloor topography in governing the geomorphology of the ECC system, and (2) the impact of the ECC fluvial system as a substratum for growth of the Holocene reef system.

The integration of a recently acquired high-resolution bathymetric dataset with literature-derived seismics, existing LIDAR, and drone-based photogrammetry datasets, illuminates the complex interplay between siliciclastic and carbonate depositional systems and their impact on sediment routing across continental margins to adjacent basins.

Our results highlight the need, in developing evolutionary models of mixed siliciclastic-carbonate continental margins, to consider multiple controlling factors of both siliciclastic and carbonate systems at both local and regional scales, without neglecting the potential influence of each system on the other. This approach needs to include late Quaternary unusually high amplitude sea-level fluctuations, pre-existing structurally controlled hinterland and seafloor topographies, and regional oceanographic and sedimentological processes.

Deltas at the shelf edge and their relationship with shelf-incising canyons

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It is not always clear why active shelf edges sometimes have a nearby canyon sometimes not. The edge of the shelf in a shelf-to-slope basin setting is dominated by delta depocenters and shelf-incising upper slope canyons. Deltas can reach the shelf edge during forced regressions or normal regressions. On the outer shelf and shelf edge, deltas commonly deliver and deposit sediments into the head of the canyon, thus accreting the upper slope, or in the case of the flows being erosional, incising the upper slope.

Using a review of well documented examples of Quaternary and pre-Quaternary shelf-edge deltas, we explain the key depositional differences between inner shelf deltas and shelf-edge deltas, and we analyze the relationship between the delta depocenter and canyon-head at the shelf-edge.

Shelf-edge deltas are overall thicker than their inner-shelf counterpart, because of the shelf gradient. Soft sediment deformation, growth faults, slumps and incisions of the delta front are characteristic of the shelf edge. Sedimentary structures as signals indicating fluvial, wave and tidal processes vary more rapidly along depositional strike and dip directions in shelf-edge deltas, compared to inner-shelf deltas, indicating more variable depositional conditions. Incisions into delta deposits are usually initiated from the prodelta and delta front rather than from delta plain channels. While there might be differences between icehouse and greenhouse shelf-edge deltas, most of the above observations about shelf-delta architecture hold true.

Slope canyons incise into the shelf and shelf-edge during times of sediment delivery directly from the river or via long-shore currents that trigger erosional sediment gravity flows. However, if the delta-front deliver too much sediment to the canyon head, the upper part of the conduit becomes choked and starts infilling. The presence of erosional versus depositional processes at the canyon head and eventually the entire architecture of the basin margin depends on the behavior of the river/delta generated gravity flows. The sediment flux, reflected in the rate of delta progradation, the sediment caliber reflected in the delta front gradient and the proximity of the delta front to the shelf-edge are proposed as key controls on erosional or depositional behavior of the flows.

Session 9: The Anthropocene – Its geo-archaeological indicators and early inceptions through the modern

A paleo-Anthropocene in Ireland? Irish Bronze Age sedimentary and faunal evidence

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Isotope zooarchaeological research in Ireland has identified a sustained positive shift in the nitrogen stable isotopic values of faunal remains during the Middle to Late Bronze Age, which has been hypothesised to have been triggered by an intensification of farming (1750-800 BCE; Guiry et al., 2018, *Science Advances*). If true, the shift would represent an indelible human footprint in the geologic record. However, whether these region-wide changes were triggered by anthropogenic factors (such as deforestation or farming activities) or by natural climatic changes, has not yet been tested. Further investigation of the phenomenon is warranted because there is evidence for episodes of land-use and climate changes during the period of interest. Focusing on samples from across Bronze Age Ireland, this paper will present results from a multi-proxy analysis of sedimentary records and herbivore remains that seeks to explore the context (and cause) of nitrogen isotopic changes identified in faunal remains in previous research. Ombrotrophic peat bogs obtain their nutrients from the atmosphere, meaning their stable isotopic values should reflect climatic fluctuations, unlike lake sediments, which should reflect both climate and land-use changes. In addition to carbon and nitrogen stable isotope measurements of sediment cores to pinpoint the timing of the shift in the isotope record, pollen (from lakes and peatlands) and testate amoebae analyses (from peatlands only) are used to reconstruct land-use and water-table fluctuations. Herbivore bone collagen stable isotopes have also been measured to extend the spatial distribution of the bone dataset presented by a previous study and to refine the timing of the change observed in the bone remains. Through this multi-proxy study, we explore the inter-relationships between the nitrogen cycle, climate and human activity and consider whether there is a case for an early Anthropocene in Ireland.

What are the key transitions within the Anthropocene? Reviewing footprints of human activity, land use, and impact in time and space as a basis for systemic sustainability

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Controversies in recognising and defining the Anthropocene stem from the inherent politics around our sustainability, and the degree to which humanity has adversely impacted the planet in such a manner that it is adequately preserved and a unique chronological marker within the global stratigraphic record. But the Anthropocene is much more than a geological timeframe; it is also a state of the human condition, and as such, notions of the Anthropocene require further integration with emerging studies of prehistory and human ecology through a social sciences lens. To many geoarchaeologists and geomorphologists, it is abundantly evident that humans have adversely affected most environments across the globe, even altering the natural hydroclimatic and biotic processes at the planetary scale to a point that threatens our sustainability. Yet, people have intensely modifying climates and landscapes and affecting ecosystems since the dawn of agriculture, city states and empires. Our premise is that deep knowledge of our past provides an important context for evaluating and assessing impact thresholds and strategic solutions for systemic sustainability.

We present an integrated socio-ecological review of the Anthropocene that synthesises environmental change in context of cultural history, political transitions, political crisis events like warfare and disease, crop collapse, soil loss, extreme weather (including hurricanes, floods, droughts), and resource availability, mineral and rock extraction, land modification – as well as the evolution of monumentality and ritual over time. We aim to better contextualise the conditions prior to the great acceleration. Looking back into Antiquity to understand prehistoric and indigenous lifeways provides some relevant examples that demonstrate the resilience of people and their societies. *What is past is indeed the prologue* – as well as the paradigm of our modern existence, which is a time in the Anthropocene when the very persistence of humans themselves is threatened by overpopulation, land misuse, pollution, and resource scarcity, all of which are conditions resulting from our cumulative "footprint."

Tracing the archaeological indicators of Anthropocene in Singida Rural District (Central Tanzania).

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African landscapes show more than others the ancient signs of the human impact on the Earth. This work aims to explore for the first time the signs of the anthropic impact in the Singida region (central Tanzania). The area, characterized by an articulated landscape with impressive geoheritages such as plateaus, inselbergs, escarpments, and impressing rocky hills and granite outcrops, was inhabited until the 1990s by hunter-gatherers' communities. Today the intensive exploitation of the land by farmers and uncontrolled activities of quarries are dramatically transforming the environment and ecosystems. One of the objectives of the interdisciplinary project carried out in the area is to detect since when human actions started to impact the landscape and the natural resources.

During the last few years, archaeological surveys, selected excavations, and ethnographic inquiries are tracing a deep history of occupation, ranging from MSA, LSA to historical tradition. The analysis of scatters of lithic artifacts, stratigraphic sequences preserved in rock shelters, and the impressive rock art evidence will contribute to reconstruct the ancient signs of the anthropic impact in the region. The paper aims to present the project's preliminary results, with a particular focus on the potential of the rock art investigation. The first use of digital tools in the recording, including iDStretch, clearly demonstrates a more complex palimpsest of styles and represented various stylistic motifs than the previous studies, and the new record constitutes an improved archive of proxy data for paleoenvironmental reconstruction and past biomes.

Keywords: *Holocene, proxy data, rock art, human environment*

Vegetation resilience in Anthropocene — an example based on pollen analysis of Lake Suigetsu, Fukui Prefecture, Japan

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It is said that we have entered a human-dominated geological epoch, eg. The Anthropocene. However, some elements of environment still have resilience and recovered due to the change of human lifestyle. This study shows one example of vegetation resilience by pollen analysis using varved sediment from Lake Suigetsu, Fukui prefecture, Japan.

Lake Suigetsu is located in Japan Seacoast. The first human activity near the lake was recorded in about 13700 cal BP and have been observed continuously after that. The vegetation in the area has changed greatly probably by both climate change and human activities based on pollen analysis. The main activities which were assumed to alter the vegetation in the area were rice cultivation, salt making, reforestation. Recently, human lifestyle has changed, and less utilization of mountain forests has also altered the vegetation. This study makes clear the turning points which altered the vegetation and recent changes using the pollen profile from Lake Suigetsu and shows the resilience of vegetation.

The vegetation change seemed to be caused by salt making in the 4th century and agricultural land transformation, ie. rice paddy cultivation in the 12th century. However, salt making did not influence the vegetation severely and the vegetation recovered soon after the impact. Great decrease of arboreal pollen and abrupt increase of Poaceae pollen were observed around the 12th century when rice cultivation became active. The impact was so great that the concentration of arboreal pollen stayed low until pine plantation started in the 15th century. Until the middle of the 20th century, forests were spotted with pine trees based on the concentration of arboreal pollen. Forest composition has changed gradually from the 20th century probably due to less forest utilization caused by petroleum fuel consumption. Pollen of pine trees decreased and evergreen Oak and other forest elements increased. It seems that forests recovered from bare condition. Japanese cedar plantation also affected the pollen profiles. Although the pollen amount was not as much as that before the 12th century, forests have changed to natural vegetation in the area.

Can Poaceae pollen serve as a proxy of human disturbance in subtropical forests? Palynology and geochemistry evidence from a wetland in southeastern China

Dr. Nannan Li [1], ***Dr. Fengling Yu*** [1]

1. *Xiamen University*

An increase in fossil Poaceae pollen percentage in a sediment core is commonly regarded as an indicator of anthropogenic activities, which might be questionable due to the limited classification and identification ability of Poaceae pollen. To assess the reliability and limitation of using Poaceae pollen as an anthropogenic indicator, we present a wetland record from the Daiyun Mountains in southeastern China. With reference to previously published pollen assemblages, we newly measured the grain size, total organic carbon (TOC) content, $\delta^{13}C_{org}$, and metal elements within the peat sediments to reconstruct the paleo-environmental history for the study area. Our findings provided different interpretations for the late-Holocene vegetation change and its driving forces for the subtropical forest in southeastern China. In line with previous palynological studies, our reconstruction confirmed that a significant vegetation transition happened around 1200 cal. yr BP: Poaceae pollen significantly increased and $\delta^{13}C_{org}$ shifted to heavier values. However, this sharp increase in Poaceae pollen is possibly not caused by intensified human impacts since no lead (Pb) or microcharcoal enrichments were observed during the same period. Instead, redox-sensitive elements suggested the increase in Poaceae pollen is mainly caused by changes in pollen source that are associated with wetland hydroclimate and water-table dynamics: During 3900 to 1200 cal. yr BP, pollen in the wetland sediments originated from the (regional) surrounding uplands and (local) wetland itself, when the peatland was a small pond/lake-like environment. However, as reflected by the sedimentary and geochemical evidence, the little pond/peatland gradually dried up after 1200 cal. yr BP and the local grasses contributed the majority of the pollen assemblage. Consequently, there is a sharp increase in Poaceae pollen within the sediment core and the pollen diagram showed an obvious vegetation transition from warm subtropical forest to open/degraded forest. Despite our records being a single core-based investigation, our multiple proxy-based evidence suggests that ancient human activities in the study area did not have significant impacts on the composition of the vegetation until recent decades. The linkage between Poaceae pollen and human activity in future paleo-records should be carefully examined using multi-proxy-based reconstructions.

Anthropocene microplastics stratigraphy in sediment cores from South China

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Microplastics (MPs) are increasingly found everywhere in the Earth surface and regarded as a major, and growing, environmental hazard. Due to widespread distribution and relatively high persistence in deposits MPs are considered a potential stratigraphic marker for the Anthropocene. However, timing of MPs accumulation is not perfectly isochronous in stratigraphic successions. In this study, stratigraphic data of MPs from two sediment cores, one from Huguangyan Maar Lake (HML), and the other from Pearl River Estuary (PRE), South China, were used to reconstruct the history of plastic pollution since 1920s. Microplastics were extracted from sediments by sieving and dense-liquid separation, and determined using micro-FTIR. The abundance of MPs in the HML sediment core ranges from 281 to 2619 items/kg·dw, and most of MPs are polypropylene and rayon fibers which may have originated from tourism activities, the scenic spot or hotel operations and atmospheric precipitation. The abundance of MPs in the PRE sediment core ranges from 511 to 3529 items/kg·dw, mainly composed of rayon and polyester fibers, which may be derived from domestic sewage discharged from upstream and coastal areas and fishery waste fishing gear, and partly from industrial wastewater and port shipping. The two MPs records show the initial increase of MPs abundance in 1950s, coinciding with the infancy of the plastic industry and onset of the Anthropocene. Subsequent rapid growth in MPs during the 1980s and dramatic increase since 2000 indicates increasing plastics production with rapid economic development at that time in China. The study confirms that MPs may serve as a strata marker for defining the start of the Anthropocene.

Global atmospheric mercury deposition flux reconstructed from natural archives 1700-2018

Dr. Qinqin Chen [1]***, Prof. Shuxiao Wang*** [1]***, Dr. Qingru Wu*** [1]***, Ms. Yuying Cui*** [1]

1. *Tsinghua University*

Mercury has contaminated ecosystems globally, but pollution management is hindered by uncertainties of mercury emissions and complicated by ongoing climate change. To better understand the impact of historical emissions and guide future mercury management and ecosystem recovery, we compiled a global atmospheric mercury deposition flux database (1700-2018), inferred from ice, peat, lake sediments, and marine sediments, with a total of 50,770 data, spanning 27 countries/regions across all continents. The inferred fluxes unanimously increased over the three centuries yet with varying levels, from four-fold (peat) to ten-fold (marine), due to different deposition mechanisms. The inferred fluxes indicate that widely adopted high mercury emissions from gold and silver mining were only of local impact and likely overestimated. Instead, coal use drives the recent rising deposition fluxes in Central Asia, East Asia, and Africa, which should be the future mercury management focus. However, rising temperatures will partly offset the effectiveness of future measures in controlling mercury emissions. We find that rising temperatures elevated mercury flux levels in temperate and tropical lakes and peatlands (ca. >12□), due to excess mercury inputs from catchments, including mercury inputs from melting ice to tarn lakes, and enhanced humification, respectively. Importantly, terrestrial environmental management is not enough to pivot increasing deposition trends in marine sediments but only decelerated increasing rates. This is evidenced by the universally increasing trends in all the available marine sediments in Europe, East Asia, and Arctica. The increasing rate in Europe, a region with one of the most stringent environmental regulations in the world, only decreased from 2%/year to 1%/year after the 1970s. Our results highlight future ecosystem restoration challenges regarding mercury pollution in the temporal and tropical lakes and peatlands in developing Asia and Africa and the marine environments across the globe under dual stresses from economic development and climate change. Future research and attention should also be paid to the health risks related to the ecosystem services, e.g., aquatic products and drinking water, provided by these deteriorated natural systems, potentially could be assisted by the global atmospheric mercury deposition flux database.

The Case for a Lunar Anthropocene: Understanding Current and Future Anthropogenic Activity on Earth's Moon

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Over two decades have passed since atmospheric chemist Paul Crutzen and ecologist Eugene Stoermer declared the end of the Holocene on Earth, arguing that humans have entered a new epoch they termed the 'Anthropocene'. However, 20 years after Crutzen and Stoermer's declaration of an 'Anthropocene,' the term has not been formally adopted by the International Union of Geological Sciences (IUGS) or the International Commission on Stratigraphy (ICS). This is largely due to disagreements about exactly *when* human activity should be measured as a clear stratigraphic marker on Earth, which is necessary to warrant its formal definition as a new epoch within the geological timescale. One issue hindering our ability to pinpoint the Anthropocene is the role of dynamic earth surface processes, which serve to erode records of human activity over time. However, these processes are not occurring on Earth's Moon, where the record of human activity has been preserved since the first impact by the Second Soviet Cosmic Rocket, Luna 2, in 1959. Here, we suggest that the recent history of space exploration, including landings, impacts, and crashes, has resulted in a measurable geomorphic signature of human activity on the lunar surface, marking a major shift in dominant geologic processes of the moon today and in the future. Indeed, since the Luna 2 impact, humans have caused 59 instances of surface disturbances on the lunar surface, or around 0.97 a^{-1} – five orders of magnitude higher than natural impact background. We suggest the shift in lunar surface processes has two important implications. First, these anthropogenic surface impacts could serve as a marker for the beginning of the Anthropocene on Earth, as they stratigraphically correlate well with proposed stratotypes for the Atomic Age – that period between 1952-1962 when atmospheric thermonuclear bomb tests were performed. Second, humans have become a dominant geological force on the moon, suggesting that it may be time to consider the presence of a distinct Lunar Anthropocene. We suggest that scientists should begin having serious discussions about our current and future impact on the Moon's surface, as well as our approach to the preservation of space heritage.

Session 10: Visualizing Science – The art of communicating science

Alexander von Humboldt's fusion of the arts and sciences in the Anthropocene

Dr. Stephen Jackson [1]

1. US Geological Survey

Humanity and nature together face three critical, intertwined challenges in the Anthropocene: rapid climate change, loss of biodiversity, and degradation of the ecological processes upon which humans and other species depend. Knowledge and action concerning all three issues rest on scientific foundations established by Alexander von Humboldt in the first half of the 19th Century. These foundations include atmospheric and ocean circulation and their mutual influences, the mediating role of terrestrial vegetation between the atmosphere and land surface, the impacts of human activities on biodiversity and earth-surface processes, the climatic determinants of species distributions and global biodiversity patterns, the impact of climate on human welfare and activities, and the fundamental sciences of the earth and its environment. Humboldt employed a variety of novel visual and graphical methods to portray and study these patterns and processes, including mapping of isotherms, vertical profiles of physical and biological data, and statistical graphs of environmental and economic data. His scientific visualizations were guided by aesthetic considerations; he aimed to convey scientific observations and processes in a visually pleasing fashion. Humboldt viewed his scientific contributions as one part of a broader, humanistic approach to understanding nature, encompassing the entire range of the arts and humanities in addition to the sciences. His humanistic approach to nature is at the heart of current concerns with environmental change in the Anthropocene. Our emotional responses to that natural world, and our sensory experience of it, are linked with our intellectual curiosity and scientific understanding, motivating our concerns with environmental change beyond the utilitarian consequences. Humboldt's fusion of the sciences, arts, and humanities provides inspiration, as well as potential maps and narratives, for developing a better and sustainable future for nature and for people.

Art & Science: promoting science through art with comic stripes and a 3D fiber-art object

Dr. Serban Raul-David [1], ***Dr. Mihaela Serban*** [2], ***Dr. Giacomo Bertoldi*** [1]

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The project “Modelling ground surface TEMPerature LINKed to remote sensing land surface temperature in mountain environments” [TEMPLINK] focuses on improving monitoring and modelling soil subsurface temperature. Ground surface temperature (GST), measured at 5 cm into the ground, is a key parameter controlling all the subsurface biophysical processes at the land-atmosphere boundary. GST is important for multiple geosciences and agricultural applications, being essential for understanding the climate change impacts on various environments. The TEMPLINK project aims to develop a model to predict soil subsurface temperatures from thermal satellite images based on numerical modeling. It represents an innovative multidisciplinary and interdisciplinary approach, combining (i) remote sensing, (ii) thermo-hydrological dynamics, and (iii) cutting-edge numerical modelling (GEOtop model and machine learning algorithms). The model will be generated at a local scale in the Mazia Valley, LT(S)ER: Open air laboratory (South Tyrol, Italy), and applied at a regional scale on the Qinghai-Tibet Plateau to test its worldwide applicability.
To facilitate the communication of this project purpose to a broad audience several outreach materials were prepared: a small cartoon booklet, a 3D fiber-art object, and a flyer. The cartoon booklet presents the project and promotes science through an animated story via comic strips for kids and youth. The fiber art object is representing a miniature 3D model of the Mazia Valley with different rope colors and textures for every land cover type. The model is accompanied by a hanging satellite also made from rope and by a flyer that explains this mix of science and art. The purpose of this object is to promote science through art for reaching a broader audience and can be exposed in art galleries, tourist info centers, or during conferences, workshops, and science fairs. Through these communication materials, the scientific project is reaching a wide audience of different ages, backgrounds, and interests.

Communicating and outreaching palaeosciences through visual arts: lessons from different realms.

Dr. Graciela Gil-Romera [1], ***Dr. Cirenia Arias-Baldrich*** [2], ***Ms. Alejandra Vicente de Vera*** [3], ***Dr. Penelope Gonzalez-Samperiz*** [4], ***Prof. Boris Vannière*** [5], ***Dr. Sarah Eggleston*** [6], ***Dr. Marie-France Loutre*** [6]

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Art and science are the two sides of the same coin; these are two ways to understand and describe the world around us and are often closely interconnected. In our rapidly changing planet, society demands sound science communication as scientific concepts need to be transmitted to the general public in the most objective, evidence-based way possible. Outreach is indeed becoming a cornerstone of our duties as academics, and it will become even more relevant in the future. A paradigmatic case is that of paleoscience where sometimes even basic principles are difficult to communicate. While paleoscience is essential to our understanding of current global change, transmitting our findings and the scope of its evidence is challenging.

In a different realm of human cognition, frequently taken far from science, we find art. Art has the power to reconcile us with our reality, reawakening the essence of the easily forgotten value of our own lives by making ordinary occasions or items enticing. Art has been used in scientific illustrations since the Middle Ages; furthermore, aside from its aesthetic value, art has an incomparable power to communicate.

In that regard, the presenting team is accruing an increasing expertise in communicating science to different audiences and through different media, and in this talk we will review different experiences we have had in communication where paleoscience and art overlapped. We will assess the efficiency of each approach, considering the objectives initially posed and the results obtained, as well as how we have been tailoring our communication projects to make paleoscience a more widely understood science. In addition, we will also explain our creative workflow in each action and the importance of using a cross-disciplinary approach in all our projects. Last, we aim to create awareness in the paleoscientific community on the central role that visual arts have when communicating science.

Communicating palaeoenvironmental data through visual art

Dr. Benjamin Keenan [1]

1. *McGill University. Department of Surface Waters, Swiss Federal Institute of Aquatic Science and Technology*

The lowland Maya ancient adapted to their changing environment in different ways, and ultimately abandoned some of their cities in response to a devastating drought around 730-900 CE. We have converted geochemical data into a high-fidelity visualisation using 'game engine' technology to represent the changing population, vegetation and climate of the ancient Maya population over 6000 years based on geochemical analyses of lipids extracted from lake sediments located adjacent to the ancient population centre of Itzan in Guatemala. The project moves beyond conventional data visualisation to create an affectual experience that enables new ways for spectators to engage with complex patterns found in scientific data. The work has been exhibited as a projected installation as well as a film.

A geological plastic-relief model to describe the subsoil of Rome

Dr. Marco Mancini [1], ***Dr. Maria Sole Benigni*** [1], ***Dr. Margherita Giuffrè*** [1], ***Mr. Francesco Versino*** [1], ***Dr. Cristina Di Salvo*** [1], ***Dr. Iolanda Gaudiosi*** [1], ***Dr. Massimiliano Moscatelli*** [1], ***Dr. Maurizio Simionato*** [1], ***Dr. Francesco Stigliano*** [1], ***Dr. Daniel Tentori*** [1]

1. *Consiglio Nazionale delle Ricerche, Istituto di Geologia Ambientale e Geoingegneria (IGAG)*

Quaternary geology, through the study of the shallow rock-sediment record, is fundamental to understand the recent dynamics of our planet and its relations with human evolution and the development of civilizations. Quaternary deposits are functional for human settlements, due to their easy digging, and commonly act as foundation soils and as a substrate for anthropogenic soils, which are often of archaeological interest.

The city of Rome, with its original settlement sited in the Central Archaeological Area (CAA) and comprising the Palatine Hill, Roman Forum and Colosseum, represents a noteworthy case to study the relations between the geological substrate and the overlaying anthropogenic soils, historical monuments and modern-age buildings. The interest of this area is well demonstrated by numerous geo-archaeological excavations, geognostic drillings, outcrops, and by a complex history of land-use transformation.

However, disclosing this large amount of information and disseminating the scientific observations deriving from these data to a wider audience is not particularly easy. Thus, we produced a 3D plastic-relief model of CAA made of polystyrene and stucco at 1:1.000 scale, representing a 1 km^2 wide topographic surface with monuments above, and showing the geologic substrate along selected cross sections up to the 100 m depth. The lithostratigraphic subsoil structure is reproduced in detail with well-differentiated: anthropogenic soils, up to 20 m thick; middle Pleistocene-Holocene fluvial formations and pyroclastic units filling paleo-valleys and interfluves; the Pliocene clayey marine bedrock.

The 3D reconstruction is useful to visualize the conditioning that external morphology and buried morpho-stratigraphic structure exert on natural risk factors. In fact, it is interesting to observe how amplification effects of seismic waves, flood phenomena and slope instability have influenced and will influence the settlement choices of CAA, the subsequent transformations, and the potential consequences of both seismic risk and future climate extremes in the city of Rome. In addition, the model also offers reconstructions of historical palaeontological excavations near the Colosseum, aimed at teaching geo-palaeontological heritage.

A collective expression of time

Dr. Anna Broström [1], ***Mrs. Annelie Nilsson*** [2], ***Mrs. Ebba Gyllenhak*** [3], ***Dr. Karl Ljung*** [4]

1. *Forn till framtid,* ***2.*** *https://annelienilsson.net/,* ***3.*** *Högskolan Kristianstad,* ***4.*** *Department of Geology, Lund University*

How can a human experience the long stretches of time under which our landscapes have been shaped? What do such experiences mean for our connection with a place and our relation to the rapid and world-transforming climate and environmental changes we are experiencing today?

In a collaborative audience participatory art project, we have explored the notion of geologic time at a particular place with the environmental history derived from a 14800-year-old sediment core as a starting point. Our project started as a workshop on the environmental history of lake Vombsjön basin in south Sweden and was part of a candidature for a UNESCO Biosphere Area. The project was a collaboration between a palaeoecologist, a geologist, an artist and landscape historian, and an artist, with participating local residents and visitors.

The artistic project explored the notion of geologic time in a collaborative effort. We used clays and gyttjas from a sediment core from lake Vombsjön as pigments mixed with locally sourced honey to produce paints. Thus, the paints had known ages were also carriers of the traces of past environments and human-landscape interactions. We used the paints to produce a collaborative painting where the participants held a large, stretched canvas between them to which all participants applied paints with ages ranging from 500 to 14500 years old. The participants also reflected on the age of the material used for the paint and aspects of where we were positioned both in time and space. The creative act of a communal painting produced a layered painting that carries the imprint of time, nature and humans, not unlike the present-day landscape. In our presentation, we will display a reproduction of the painting and a video of the performance, and discuss the connections between scientists, artists, the audience, and the changing landscape.

Using Virtual Field Trips to Visualize and Communicate Quaternary Volcanism in the Black Rock Desert, Utah

Dr. Tiffany Rivera [1], ***Dr. Brian Jicha*** [2]

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Students of geology find placed-based learning to be one of the most beneficial aspects of their education. However, during COVID, it became clear to educators that our method of placed-based teaching is not a guaranteed pedagogy. The pandemic led to geoscience educators exploring innovative technologies to immerse students in field studies without having to be present in the field. This led to the development of virtual field trips which include immersive, online, multimodal, interactive activities that leverage technology and the availability of global satellite data. As we have returned to in-person teaching and the ability to return to our field areas, there is still a strong desire by the geoscience community to produce and use virtual field trips as they increase accessibility of field sites for (1) students who may have mobility differences, (2) for trips that may be cost-prohibitive, (3) for students that are primary caregivers or heads of households. Further, virtual field trips can reduce inequities and improve fairness within the learning environment. In Utah (USA), the Black Rock Desert consists of 2.5 Ma to Recent bimodal, monogenetic volcanism. Episodic volcanic activity produced intriguing landforms and features including cinder and tuff cones, lava tubes, a lava lake, rhyolite domes, pyroclastic deposits, and obsidian flows. This virtual field trip takes the viewer through a series of locations that were chosen to best represent the uniqueness of Black Rock Desert, and aims to increase the general public's knowledge and awareness about geologically young volcanism in central Utah. This self-guided field trip was developed using the Google Earth Web platform, which allows the creator to add images, Google Street View 360 images, videos, web links, and text to map locations that are combined into a trip. In addition, we have developed a K-12 and college-level curriculum that can supplement the field trip.

Stories about climate: Communicating climate science to teenagers with hands-on activities and a comic book

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Climate change is a source of concern, especially for the younger generations. The potential impacts of the global temperature rise based on climate projections are widely discussed through the media. However, climate science is rarely presented from a long-term perspective, using historical and past climate reconstructions despite its relevance to understanding natural climate variability. The objective of this project was to communicate about paleoclimatology by introducing examples of four methods currently used to reconstruct the climate of the past: micropaleontology, dendrochronology, historical climatology, and local knowledge.

The project is a workshop, online or live, that targets teenagers specifically. Two types of educational materials were produced: a booklet of activities and a comic book. In the booklet of activities, each section starts with description of the methods and ends with an interactive activity. The booklet ends with a take-home exercise for which the participant is asked to interview an elder on his/her perspective of climate change. The comic book tells the story of a youth who undertakes fieldwork in the Inuvialuit Settlement Region in northwestern Canada, searches databases, and experiences exchanges with knowledge holders, scientists, and students. In the comic book, the main character finds clues about the climate of the past in the Mackenzie Delta and finally reconstructs the climate of the last hundreds of years, allowing comparisons with the impact of ongoing global warming.

The local knowledge section was developed through interviews with members of the community of Aklavik. The interviews were used and referred in the educational materials. Throughout the production process, we sought feedback and approval for dissemination from the community of Aklavik. This interdisciplinary science communication project is an example of knowledge mobilization between Indigenous and other local knowledge holders, organizations, and scientists. It also served as an example for the scientific community to team up with local artists to prepare activities visually attractive for a non-scientific audience, and thus contributed to knowledge transfer and bridging the science-community gap.

Exploring the capacity of climate art to communicate climate change from a cultural perspective

Ms. Svetlana Radionovskaya [1]

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The word «art» can be interpreted in very different ways. Institutions such as museums, galleries and art schools, and art critics are the pinnacle of contemporary art and set certain «trends», which are easily spotted in contemporary galleries. Conceptual artworks presented in these exhibitions often go on to generate thousands-to-millions of pounds at art auctions therefore creating an elitist art world.

How can contemporary visual arts (and can they) offer different ways of imag(in)ing the problem of climate change, which would create an experience beyond visual (i.e. emotive and behavioral)? Here, I review «historical» climate art and propose that climate art can be split into three categories: representations (emphasizing visualization and communication of climate change); performance and conceptual art (engagement through immersion and experience); and interventions such as public engagement and activism (invoking motivation to take action). What are the challenges associated with these categories?

According to the art world, the *good art*, i.e. the conceptual art, or “art for art’s sake” as originally described by Clement Greenberg in 1940, appeals and creates a desired experience for a limited amount of people with an attained cultural capital, and thus, I argue that it ultimately fails to communicate climate change to the wider public; yet it’s the preferred category of the art institutions. In the meantime, the *bad art*, which is more illustrative and communicates the climate message clearly, disinterests artistic institutions and critics. This slowed the development, and led to a decline of climate art produced, or displayed in galleries in the late 2000s and early 2010s; however an explosion of climate art popularity has since occurred in the last five years, likely because the issue of climate change has been brought to the forefront of political debate and contemporary culture. Therefore, it remains an open question how to best portray, communicate and create an “ultimate” experience of climate change through art and how to assess the success of these pieces (eg. art critics opinions, public opinions/ interpretations, amount of income generated); but it is clear that collaboration between scientists and artists is desperately needed to develop climate art.

Rethinking Palaeclimatology for Society: co-production strategies for policy engagement

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There is a recognised gap between data generated by environmental and climate scientists and evidence needed by policy makers. This is in part because influencing policy through research is complex and requires skills that might not be valued or common in research systems such as fundamental training in science communication. In particular, Quaternary scientists do not often have impact beyond academia because research questions are theoretically driven instead of responding to societal needs. The current situation of our Earth's system, together with the social movements for climate justice, urge a step change in how policy and scientists approach climate change.

Funded by UK Research and Innovation and supported by both Ministerial Departments and stakeholders, we (the Decadal team formed by palaeclimatologists and Quaternary scientists) are developing a co-production model of research where scientists and end users work in a synergy to develop research questions, produce research, and communicate effectively, to contribute to the policymaking system. Evidence-based insights and improvements in how to better communicate uncertainties to both policy and media are key areas to develop. We discuss, from a scientist's perspective, our communication strategies to engage with policy makers and how to establish closer relationships, reputation and trust, with the shared goal of improving how science is used in decision making. This work is a contribution to the Decadal project.

Time Travel Machines and Other Forms of Science Communication

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1. *Cooked Illustrations,* ***2.*** *The Smithsonian Tropical Research Institute*

Tropical countries have attracted natural scientists from western cultures for centuries, but there remains a profound disconnect between the science and the citizens of tropical regions, especially at the young educational level with pervasive and lasting cultural impoverishment. Panamá has been host country to the Smithsonian Tropical Research Institute for nearly 100 years and is replete with unique geological, paleontological and archeological histories, and yet many people on the Isthmus of Panama remain in the dark about this rich history. In this presentation we showcase Martina and The Bridge of Time–A children's book that aims to offer provision to fill an educational gap. Developed between a visual storyteller and scientist, Martina is a young girl full of questions about her homeland and its history. After finding no answers in her own history books, Martina builds a Time Machine and travels back through time to witness Panama's geological, biological and human history for herself. Martina and the Bridge of Time shows how a deep interest in place can be a core technique in communicating complex ideas to diverse audiences. Focusing on the audience's relationship to their local environment and identifying how these relationships can overlap with existing science stories extrapolated from scientific research can have powerful resonance with local audiences regardless of format. The success of Martina and the Bridge of Time shows the power and potential of intellectual properties as not just carriers of scientific research messaging, audience development and engagement, and ways to develop successful outreach programmes, but also as a tool through which new methodologies of engagement and sustainability can be developed. We use this, and other case studies, to help explore how scientific researchers and creatives can collaborate to produce effective projects that meet both audiences' needs and outreach goals.

A cosmopolitan genome from Valencia during the Roman Empire

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An excavation in the vicinity of the ancient Roman forum of Valencia (Spain) brought to light a series of burials as well as Iron Age Iberian ceramics and other material remains from the Roman period were found in what could have been the river harbor of the city. The majority of tombs were medieval in origin and were linked to the now disappeared parish cemetery of San Lorenzo.

In the oldest strata, two Roman tombs surfaced, a much rarer finding in this part of the city. We were successful in recovering ancient DNA from one of the two individuals, whose remains were mixed with the lower jaw of a pig. The sample was exceptionally well-preserved and revealed a level of endogenous DNA of around 30%, six times higher than usual. This allowed to shotgun sequence the genome to a coverage of 2X, to our knowledge the highest covered genome from the Roman period in Spain. We also radiocarbon dated the sample and obtained and estimated age between 250-400 CE. We determined the genetic sex to be female.

The mitochondrial DNA lineage we recovered from this female is called D4e1. D4 lineages are extremely rare in Europe in ancient and modern populations, but D4e1 exists as the sole European branch representative of the D4 clade (found in 3 modern European samples from Austria, Greece and Czechia). All lineages related to D4 originate in Asia and the others that exist today are common and almost exclusive to East and South Asia.

Our analyses did not find recent traces of Asian admixture. However, the analyses revealed certain genetic affinity to various population while being distinct from all of them. We found that the genome of this woman was a mosaic of genomic contributions from three different sources across the Mediterranean: Iberia, an unidentified central/eastern Mediterranean population and a minor North African source. The high levels of heterozygosity indicate that she is the product of a recent admixture, highlighting the cosmopolitan nature of the inhabitants of the city at th time.

Session 11: Proxy-based reconstructions of atmospheric and oceanic patterns

Distinct phases of peatland carbon accumulation in the southern mid-latitudes driven by southern westerly wind shifts

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Peatlands have been increasingly recognised as an important part of the carbon budget, with estimates suggesting they account for up to 30% of terrestrial global carbon storage. While the most extensive peatlands are found in the Northern Hemisphere, there are substantial deposits in the mid- to high- latitudes of the Southern Hemisphere, but these are underrepresented in global syntheses due to sampling bias. To investigate the timing and drivers of widespread peatland initiation in the southern mid-latitudes after the Last Glacial Maximum, we sampled and radiocarbon-dated basal peats from across sub-Antarctic islands of the South Atlantic region, and collated published basal peat radiocarbon ages from peat forming regions >35°S. We use Kernel density estimate models to investigate spatial and temporal phases of peat initiation and compare with climate proxy records to test climatic drivers. Peat initiation in the southern mid-latitudes commences 20,000 cal years BP and peaks at 13,000 years BP, suggesting that climates were favourable for peat growth at this time. We propose that phases of peat formation identified across different latitudinal belts are driven by a combination of warming temperatures and shifts in latitudinal position and strength of the southern westerly winds, which directly drive precipitation (and effective precipitation) changes in the mid-latitudes. In recent decades, warming of the southern mid-latitudes has accelerated, coupled with a southward shift of the SWW since the mid-20th century. While the impact of these shifts on the establishment and rate of peat accumulation is currently not well constrained, implications from this study suggests that a continuation of these trends may result in net carbon losses.

Plio-Pleistocene variability in the strength of the Pacific Walker Circulation

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Observations from general circulation models and theory suggest that the Pacific Walker Circulation will weaken as temperatures increase from anthropogenic CO_2 emissions. Despite strong evidence, detecting changes in the Pacific Walker Circulation is hampered by the short duration of the instrumental record. Atmospheric CO_2 concentrations during the Pliocene were similar to contemporary concentrations and global temperatures were 2 to 3 °C warmer, making the Pliocene a useful analog to constrain future changes in the Pacific Walker Circulation and benchmark climate simulations. Recent observational studies have demonstrated that isotopes of water vapor in the eastern and western Pacific encode changes in the strength of the Pacific Walker Circulation. In light of this, we develop two records of precipitation isotopes (dD_{precip}) from C_{30} *n*-alkanoic acids in the eastern (ODP1239; 0.672 °S, 82.08 °W) and western Pacific Ocean (ODP1143; 9.362 °N, 113.29 °E) to reconstruct the Plio-Pleistocene evolution of the Pacific Walker Circulation. In the western Pacific, dD_{precip} from site 1143 demonstrates a gradual enrichment which reflects changes in convection, water vapor source, and large-scale dynamics. A long-term increase in dD_{precip} in the eastern Pacific at site 1239 reflects a complex history of regional changes in sea surface temperatures, Andean uplift, and atmospheric circulation changes. Collectively, these two records highlight a complex evolution of the Pacific Walker Circulation through the Plio-Pleistocene, which we interpret in the context of isotope enabled models and modern observations.

New insights into surface-ocean dynamics of the NE Atlantic Ocean across the penultimate interglacial complex from planktic foraminiferal assemblage record of the IODP Site U1385

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Marine Isotope Stage (MIS) 7 (246-190 ka) is uniquely characterized by large amplitude fluctuations of orbital parameters with reduced CO_2 concentrations. Consequently the global ice-volume fluctuated rapidly during MIS 7e to 7c. Therefore, investigation of this rapid switching from the glacial to interglacial state may provide new insights into the understanding of mechanism and feedback processes for climatic shifts. However, studies dealing with MIS 7 are constrained by lack of continuous high-resolutions records with well-established age model. The Iberian margin is an ideal region to obtain high-resolution records of past climatic changes on millennial-centennial timescales which can be compared with records of different climatic regions. We present here planktic foraminiferal assemblage and ANN-based SST records integrated with existing log (Ca/Ti), δ^{13}C and δ^{18}O datasets from IODP Site U1385, off SW Iberia to analyze the pattern and amplitude of climatic events interrupting MIS 8-7 termination, MIS 7 and the MIS 6 inception and to assess the role of atmospheric/hydrological factors on productivity variation and the associated surface-ocean dynamics at centennial-millennial scales.
Our records suggest overall increase in productivity and Iberian pole-ward current (IPC) influence during the warmer sub-stages 7e, 7c and 7a, whereas the colder sub-stages 7d and 7b are characterized by reduced productivity and IPC influence. Moreover, the warmer sub-stages show two-fold variations in productivity and IPC influence. Early phase of sub-stages at MIS 7e (~240-235 ka), 7c (~220-216 ka) and 7a (~202-198.5 ka) suggest low to moderate productivity with increased IPC influence. The weaker trade winds coupled with strong westerly influences over the SW Iberian region might have caused the weakening of upwelling due to the southern shift of the Azores High, a condition similar to the present-day negative North Atlantic Oscillation (-NAO)-like mode. Conversely, late phase of sub-stages at MIS 7e (~235-229.5 ka), 7c (~216-211.5 ka) and 7a (~198.5-195 ka) indicate moderate to high productivity with decreased IPC influence, a condition similar to the present-day +NAO-like mode. Furthermore, severe SST drops with significant productivity reductions are recorded around ~250, 243, 230, 219, 204, 195 and 192 ka, due to stratified waters caused by melt-water arrival from ice-rafting.

The OC3 global data base: high-resolution stable isotope data from benthic foraminifera of the last deglaciation

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In paleoceanography, carbon and oxygen stable isotope ratios from benthic foraminifera are used as tracers of physical and biogeochemical properties of the deep ocean. We present the first version of the Ocean Carbon Cycling working group database, of stable isotope ratios of oxygen and carbon from benthic foraminifera in deep ocean sediment cores from the Last Glacial Maximum (LGM, 23−20 ky before present (BP)) to the Holocene (< 10 ky BP) with a particular focus on the early last deglaciation (20−15 ky BP). It includes 287 globally distributed coring sites, with metadata, isotopic and chronostratigraphic information, and age models. A quality check was performed for all data and age models. Sites with at least millennial resolution were preferred, because the main goal is to resolve ocean changes associated with the last deglaciation on at least millennial timescales. Software tools were produced to access and analyze the data, and are included with this publication. Deep water mass structure as well as differences between the early deglaciation and LGM are captured by the data in the compilation, even though its coverage is still sparse in many ocean regions. We find high correlations among time series calculated with different age models at sites that allow such analysis. The database provides a useful dynamical approach to map physical and biogeochemical changes of the ocean throughout the last deglaciation.

Last Glacial Maximum Lake sediments capture High Arctic surface warming during Heinrich Event 2

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Throughout the Last Glacial period, widespread deposition of Ice Rafted Debris (IRD) marks phases of North Atlantic ice sheet instability during cold Stadial conditions. The causes for these so-called Heinrich Events (HEs) remain contested: while initially attributed to internal ice sheet dynamics, there is mounting evidence for external ocean-climate forcing. In the latter scenario, ice rafting was driven by basal melt from a build-up of sub-surface heat in response to weakening ocean circulation. However, coeval shifts from perennial to seasonal sea ice conditions suggest that some heat may have escaped to the surface. We strengthen this notion, by presenting biomarker-based evidence for atmospheric warming from a unique Last Glacial Maximum (30-20 ka BP) lake sediment sequence from High Arctic Svalbard. Alkenone-derived changes in temperature (UK37) and hydroclimate (δD) indicate a rapid shift towards warmer surface conditions and more locally sourced precipitation at the onset of HE 2. These findings are supported by XRF evidence for lake water stratification and a shift towards *n*-alkane distributions indicative of less arid conditions. In conclusion, our data suggests that climate-forced Arctic ice sheet instability during HEs was triggered from below as well as above.

Foraminiferal assemblage response to Mediterranean and Atlantic changes during last deglaciation: A report from the Mediterranean overflow

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The last 30 ka period is marked by abrupt global changes, in which ocean thermohaline circulation, ice sheets and atmosphere interacted during deglaciation. In the Mediterranean basin, in addition to these changes there were others related to its own thermohaline circulation. Here we use foraminiferal assemblage data to infer paleoenvironmental changes from last 30 ka BP at ~600m depth, on the main branch of Mediterranean Overflow Water (MOW) in gulf of Cadiz. High sensitivity of foraminifera to environmental changes, with species-specific responses, and key location of the studied site allow to reconstruct NE Atlantic surface properties from planktic species and Intermediate Mediterranean water properties from benthic species.

Results showed that MOW strength is imprinted in this site by relative peaks in abundance of elevated epi-fauna, species associated with strong bottom currents and arrivals of shallow shelf reworked taxa. Sequences of benthic assemblages are well-correlated to Eastern Mediterranean dynamics even during periods of depleted ventilation and outflow as sapropel-1, which is the time interval with relatively most severe conditions. During this sapropel-1 period it is reflected the two different sapropel phases, separated by the 8.2 ka event. Heinrich stadial 1 (HS-1) is characterized by a relative peak of infrequent Mediterranean taxa and dominance of species tolerant to organic matter accumulation during its early phase, as observed in Atlantic Intermediate water sites during this period. This is consistent with sinking of MOW and a higher Atlantic influence during HSs. Matching between the studied site and Levantine basin irrespective of MOW strength makes this site valuable to study past changes in Mediterranean basin, excepting moments of MOW core sinking, in which Atlantic influence is notable.

No substantial northward shift of the North Atlantic Polar and Arctic fronts during the mid-to-late Younger Dryas

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The Younger Dryas (YD) stadial is a key period for analysing abrupt climate change. Numerous proxy records of oceanographic changes exist for the YD interval, but reconstructions focus on a few records, extrapolated to represent basin-scale patterns. While model simulations can achieve broadly similar conditions to the marine proxy reconstructions for the period, unrealistic amounts of freshwater are required to obtain these conditions. Weakening of the Atlantic Meridional Overturning Circulation (AMOC) via freshwater input has been cited as the cause of the Younger Dryas but this does not capture the variable conditions seen within the stadial across the North Atlantic region. For example, several terrestrial reconstructions of climate have suggested that migration of the marine Polar Front northwards began mid-way through the YD and that climate over northwest Europe ameliorated from this point in time too, broadly contemporaneous with the deposition of the Vedde Ash (~12 ka Cal BP), a widespread isochron for the North Atlantic region. This work aims to examine the basin-scale changes in surface water conditions within the North Atlantic, using existing and new foraminiferal surface records of change.

A compilation of 82 palaeoceanographic records focused on the YD period is presented for the North Atlantic (~53 - 79°N, -60 - 22°E), using reconstructions of sea surface conditions via proportions of the polar-front indicating *N. pachyderma*. Due to sampling resolution and chronological challenges for many cores, and to effectively test this proposed amelioration in conditions at ~12.1 ka Cal BP, a time-slice approach was adopted, with conditions in the early-YD and the late-YD spatially interpolated. No significant changes were reconstructed from early to late YD based on *N. pachyderma* records, and indeed northward heat transport likely persisted throughout the YD. Minimal changes occur in foraminiferal $\delta^{18}O$ records, although some reduced values within the NW Atlantic in the late-YD may relate to freshwater release via the Hudson Strait or Greenland Ice Sheet. Although often invoked as a mechanism for ocean-atmospheric climate changes, the Polar Front did not appear to shift during the YD, and so alternative mechanisms are required to explain the terrestrial variability evident within YD.

Forcing of Holocene hydro-climatic variability at the North African desert margin inferred from multi-proxy frequency analyses (Lake Sidi Ali, Morocco)

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The North African desert margin is considered one of the most sensitive areas to future climate changes. Improved knowledge about Holocene climatic variability and environmental responses on millennial to centennial scale will help to refine scenarios related to future climate changes. During the last two decades, the advances in the study of Holocene and last glacial records from the subtropical North Atlantic and the Mediterranean areas have improved our knowledge about the millennial-scale variability of the Western Mediterranean palaeoclimate and the Saharan dust cycle. The detection of periodicities can help to identify or refute particular forcing mechanisms. To detect periodicities in Holocene climatic variability and geomorphological processes, we use a Holocene sediment record from Lake Sidi Ali in the sub-humid Middle Atlas with a ^{210}Pb and pollen-based ^{14}C chronology. In order to distinguish between lake-internal (e.g. chemical precipitation) and lake-external (e.g. detrital input) processes, which might be driven by varying hydro-climates. We use a high resolution XRF-core scanning record calibrated with conventional ED-XRF analyses. Redfit and Wavelet timeseries analyses reveal distinct periodicities from millennial to centennial scales. The XRF element records reveal three Redfit Proxy Groups (RPG) with distinct periodicities potentially reflecting different forcings which were derived by a correlation analysis of extracted, highly significant frequency analysis spectra. Further, we integrated environmental and climatic proxies from the same core (*Cedrus atlantica* pollen abundance, magnetic susceptibility, δ^{18}O and δ^{13}C values of ostracod shells, grain-size endmembers and total organic carbon) and use their wavelet domains. We identify two main periodicity regimes that affect both, the hydrological regime and the lake productivity and catchment erosion dynamics. The hydrological regime seems to be mainly controlled by Precipitation-Evaporation balances (incl. winter rain variations) driven by North Atlantic and solar forcing (2 kyr and 1 kyr periodicities) as suggested by evaporation related proxies (Ca, Sr, Ca/Ti, Sr/Ti). In contrast, the lake productivity seems to be driven by summer temperature variations. Non-winter related processes (detrital input: Fe, Ti, K, etc. and lake productivity: Si/Ti) have independent periodicities (3.5 kyr and 1.5 kyr) and might be forced by solar and North Atlantic controls.

Evaluation of the predictable component of natural climate variability during the Holocene

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The oscillatory behaviour of the climate system on decadal timescales beyond the instrumental record is hard to quantify. Yet knowledge of it is vital to support climate predictions and to put current changes in context of past experiences. We investigate the recurrent component of weather and climate variability in the North Atlantic sector during the Holocene in proxy data. We apply time-frequency analysis to both an annually-laminated climate record from a lake in England, and the Atlantic Meridional Overturning Circulation in a long transient simulation to demonstrate that decadal variability was consistent over the last 6,700 years and prior to 8,500 years before present, which was predominantly linked to solar and ocean forcing. Between these dates, climate variability was dampened on decadal timescales. Our results suggest that meltwater discharge into the North Atlantic and the subsequent hydrographic changes, from the opening of the Hudson Bay until the final collapse of the Laurentide Ice sheet, disrupted the regular climate patterns: suspending the decadal cyclic signals, and lowering the predictable signal of the climate system. Our results have relevance for near-term climate predictions given the current acceleration of the Greenland Ice Sheet melting in response to global warming.

Wind regime changes in the North Atlantic-European region driven by Late-Holocene Grand Solar Minima

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Understanding atmospheric responses to radiative forcing, including the intensity and distribution of wind patterns, is a critical issue, as this might have important implications in the coming decades. Long-term episodes of reduced solar activity (i.e. Grand Solar Minima, GSM) have triggered rapid climate change in the past, recorded in proxy-based records, including varved sediments from Meerfelder Maar, Germany, where the impact of the Homeric GSM (~2800 years ago) was studied. Here we present a reconstruction of increased windy conditions during the same GSM from another varved record, Diss Mere, in England, to support the solar-wind linkage in the North Atlantic-European region. We use diatoms as proxies for windiness and support the palaeolimnological and palaeoclimate interpretation with a multi-proxy approach, including sedimentological, geochemical, and biological (chironomids and pollen) evidence. The diatom assemblage documents a shift from *Pantocsekiella ocellata* dominance to *Stephanodiscus parvus and Lindavia comta*, indicating a shift to more turbulent waters from ~2767 ± 28, linked to increased windiness. This shift is synchronous with changes in ^{14}C production, linked to solar activity changes during the GSM. Both proxy records reflect a rapid and synchronous atmospheric response (i.e. stronger winds) at the onset and during the GSM in the North Atlantic and continental Europe. In order to test whether this solar-wind linkage is consistent during other GSMs and to understand the underlying climate dynamics, we analyse the wind response to solar forcing at the two study sites during the Little Ice Age, a period that includes several GSMs. For this, we have used a reconstruction based on a 1200-year-long simulation with an isotope-enabled climate model. Our study suggests that wind anomalies in the North Atlantic-European sector may relate to an anomalous atmospheric circulation in response to long-term solar forcing leading to north-easterlies modulated by the East Atlantic pattern.

Phase 4 of PAGES 2k: Hydroclimate of the Common Era

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The climate of the past two millennia (2k) is vital for developing our understanding of the climate system, as it extends the historical climate record and provides context for recent and future changes. Building on previous phases of the PAGES 2k network, Phase 4 paves the way for a new level of understanding of the global water cycle and enhanced science-policy integration.

Previous PAGES 2k network phases, emphasising temperature reconstructions, fundamentally improved our understanding of global climate changes over the Common Era. These reconstructions received widespread recognition and were featured in the Summary for Policymakers of the IPCC's Sixth Assessment Report. Integration of this data with state-of-the-art Earth systems models, proxy system models and data assimilation yielded a more comprehensive understanding of the associated physical drivers and climate dynamics.

Phase 4 challenges our community to turn its focus towards hydroclimate. Our overarching aim is to reconstruct hydroclimate variability over the Common Era from local to global spatial scales, at sub-annual to multi-centennial time scales, developing a process-level understanding of past hydroclimate events and variability. Our multi-faceted approach includes (1) developing new hydroclimate syntheses that are well-suited for data-model comparisons, (2) improving the interoperability and scope of our data and model products, and (3) facilitating the translation of our science into evidence-based policy outcomes. In this presentation, we report on our activities and progress to date, particularly highlighting the early stages of our data synthesis efforts.

Clam shells reveal the subpolar North Atlantic tipped into the Little Ice Age

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The cooling transition into the Little Ice Age was the last notable shift in the climate system prior to anthropogenic global warming. It is hypothesised that sea-ice to ocean feedbacks sustained an initial cooling into the Little Ice Age by weakening the subpolar gyre circulation; a system that has been proposed to exhibit bistability. Empirical evidence for bistability within this transition has however been lacking. Using statistical indicators of resilience in three annually-resolved bivalve proxy records from the North Icelandic shelf, we show that the subpolar North Atlantic climate system destabilised during two episodes prior to the Little Ice Age. This loss of resilience indicates reduced attraction to one stable state, and a system vulnerable to an abrupt transition. The two episodes preceded wider subpolar North Atlantic change, consistent with the destabilisation of the subpolar gyre and the approach of a tipping point, potentially heralding the transition to Little Ice Age conditions.

Global warming has caused synchronous drying trend over most parts of the Europe since 1860s

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Widespread and frequent droughts are affecting most parts of the Europe in recent years, but it remains unclear when such synchronous drying trend started and how anthropogenic forcing influences. Here we present a new annually resolved tree ring stable oxygen record to reconstruct southern European hydroclimate over the past 300 years. Our reconstruction suggests that the onset of southern European drying trend occurred around 1860s, which marks the onset of extensive drying over most European area except the wetting northern Europe. We demonstrated that global warming has favored decreasing rainfall and increasing evaporation. With enhanced land-atmosphere coupling, the current drought intensification over most parts of the Europe is potentially irreversible.

Interactions between contemporary regional atmospheric dynamics and stable water isotopes in the Southern Ellsworth Mountains, West Antarctica

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Firn core water isotope (δ^2H, $\delta^{18}O$) records spanning the late 20th and early 21st century from the Ellsworth Mountains suggest that climate in the 'coastal interior' of the West Antarctic has remained stable over the last few decades. This stability sits in contrast to several ice core records proximal to the Amundsen-Bellingshausen seas, which preserve a signal of late 20th century warming driven by regional climate dynamics, such as the strengthening of the Southern Annular Mode (SAM). Direct temperature measurements from the southern edge of the Ellsworths at Patriot Hills record intermittent, extreme high temperature events during the same time period. These events are driven by high-pressure blocking systems over the Antarctic peninsula that disrupt westerly airflow around the continent, facilitating the delivery of warm air from the Amundsen-Bellingshausen to the West Antarctic interior. To investigate the interaction between the atmospheric circulation and climate signals preserved in local precipitation, we utilise a combination of novel water isotope measurements, major ion chemistry data, and contiguous HYPSLIT airmass back-trajectory modelling. We report on a new 40-year record of contemporary water isotope data from Patriot Hills, extending the current Ellsworth Mountains firn core network a further 60 km south. Using ERA-5 reanalysis data, we conduct contiguous, 5-day atmospheric back-trajectories with the NOAA HYSPLIT model to Patriot Hills over the time period covered by the firn core. We analyse our trajectory data with a synoptically representative clustering scheme, allowing us to generate time-series of bulk and precipitating airmass delivery from different regional sectors such as the Weddell, Amundsen-Bellingshausen, and Ross seas. We evaluate the role of SAM and other climate modes in influencing both local climate and its translation into the preserved water isotope record. Patterns in precipitation-associated airmass delivery are explored as indicating a possible bias in precipitation towards airmasses arriving from the Weddell Sea, potentially masking the influence of warming associated with the Amundsen-Bellingshausen.

Bayesian Methods for Proxy Uncertainty Quantification, with an application using Machine Learning.

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The study of past environments have strongly rely on proxy analysis to offer indications from past events that could have change the climate and/or environment. These proxies are found in different types of sediments, and the development of age-depth models has been critical in putting these variations in proxies into a temporal framework. Age-depth models have evolved into complex structures that give not only a point estimator but also a density estimator in the form of hundreds or millions of data from a probability distribution. Unfortunately, there is presently no tool that can include the posterior distribution from the age-depth model into the proxy analysis. As a result, users of age-depth models would only utilise the age-depth model's mean in their analysis. In this session, we will present PUlQue, a recently created tool that permits the use of age-depth posterior distributions in proxy research. This tool provides a proper statistical analysis for proxy analysis without ignoring age uncertainty. Using the results from this tool and instrumental data for Atmospheric Rivers, we trained a machine-learning method to predict Atmospheric Rivers in the sediment record from a lake in California (USA).

Session 13: Records of LGM climate and ecosystems dynamics

The LGM record in unglaciated NW Canada, far-eastern Beringia, recorded by pore ice water isotopes, eDNA and macrofossil evidence from relict permafrost

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Relict permafrost in the Klondike region of northwestern Canada records LGM conditions in unglaciated far-eastern Beringia through multiple proxies including pore ice water isotopes, plant and insect fossils, eDNA and vertebrate records. These proxies provide a detailed picture of the transition from open boreal conditions near treeline during MIS 3 to increasingly arid and cold conditions going into the LGM. Bison were prominent during MIS 3, while horses increased in abundance with cold and dry conditions and the initial development of steppe-tundra after ~ 35,000 cal yrs BP. Near the LGM, pore ice water isotopes reach a minima at ca. 16,000 to 19,000 cal yr BP associated with the coldest conditions of the Late Quaternary. Nitrogen isotopes from soil organic matter indicate an enrichment associated with increased aridity, while d-excess from the pore ice is consistent with decreased summer contributions to soil moisture. Full glacial environments (ca. 16,000 to 19,000 cal yr BP) supported steppe-tundra vegetation and an insect fauna dominated by Connatichela artemisia - an endemic weevil associated with prairie sage (Artemisiae frigida). Evidence for the collapse of the mammoth steppe ecosystem begins with slowing of loess accumulation and development of paleosol ca. 13,500 cal yr BP. At this time, Connatichela artemisiae becomes infrequent and Artemisia pollen declines and is replaced by Cyperaceae, before mesic shrubs become dominant. The establishment of shrub tundra is associated with rapid changes in pore-ice isotopes, suggesting that ecological turnover coincided with a shift in atmospheric circulation and moisture availability. Finally, boreal vegetation communities became established ca. 10,500 cal yr BP. Collectively, these data show the close-coupling between late Quaternary large mammal populations, vegetation, insects and pore ice water isotopes providing a detailed archive going into, during and following the LGM in far-eastern Beringia.

Synchronizing ice-core and U/Th time scales in the Last Glacial Maximum using Hulu Cave 14C and new 10Be measurements from Greenland and Antarctica

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Between 15 and 27 ka b2k (thousands of years before 2000 CE) during the last glacial, Greenland experienced a prolonged cold stadial phase, interrupted by two short-lived warm interstadials. Greenland ice-core calcium data show two periods, preceding the interstadials, of anomalously high atmospheric dust loading, the origin of which is not well understood. At approximately the same time as the Greenland dust peaks, the Chinese Hulu Cave speleothems exhibit a climatic signal suggested to be a response to Heinrich Event 2, a period of enhanced ice-rafted debris deposition in the North Atlantic. In the climatic signal of Antarctic ice cores, moreover, a relative warming occurs between 23 and 24.5 ka b2k that is generally interpreted as a counterpart to a cool climate phase in the Northern Hemisphere. Proposed centennial-scale offsets between the polar ice-core time scales and the speleothem time scale hamper the precise reconstruction of the global sequence of these climatic events.

Here, we examine two new ^{10}Be datasets from Greenland (NorthGRIP) and Antarctic (WDC) ice cores to test the agreement between different time scales, by taking advantage of the globally synchronous cosmogenic radionuclide production rates.

Evidence of an event similar to the Maunder Solar Minimum is found in the new ^{10}Be datasets, supported by lower-resolution radionuclide data from Greenland and ^{14}C in the Hulu Cave speleothem, representing a good synchronization candidate at around 22 ka b2k. By matching the respective ^{10}Be data, we determine the offset between the Greenland ice-core time scale, GICC05, and the WDC Antarctic time scale, WD2014, to be 125±40 years. Via radionuclide wiggle-matching, we determine the offset between the Hulu speleothem and ice core timescales to be 375 years for GICC05 (75–625 years at 68 % confidence), and 225 years for WD2014 (-25–425 years at 68 % confidence). The undercounting of annual layers in GICC05 inferred from the offset is hypothesized to have been caused by a combination of underdetected annual layers, especially during periods with low winter precipitation, and misinterpreted unusual patterns in the annual signal, during the extremely cold period often referred to as Heinrich Stadial 1.

A 35 ka chironomid record and summer temperature reconstruction covering the Last Glacial Maximum from Bergsee (Black Forest, Germany)

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The intermediate location of Bergsee (382m a.s.l.) between the Black Forest and the Alpine glaciers makes it a unique palaeoenvironmental archive that probably recorded the entire Last Glacial Period. Here we present a chironomid record from this lake covering ca. 35 ka including the Last Glacial Maximum. The record is divided into 6 statistically significant biostratigraphical zones. Between ca. 45–32 ka taxa typical for the littoral of relatively warm lakes (*Parakiefferiella bathophila*-type, *Paratanytarsus* and *Tanytarsus pallidicornis*-type) are dominating. Then (ca. 32–24 ka) *Sergentia coracina*-type, a profundal and cold indicative taxon, becomes dominant alongside *P. bathophila*-type. Low diversity and high abundances of *S. coracina*-type suggest the most severe environmental conditions of the record. The third zone (ca. 24–21 ka) is largely dominated by *P. bathophila*-type and warmer indicative taxa replace *S. coracina*-type. In the fourth zone (ca. 21–17 ka) *Paratanytarsus* and *Tanytarsus pallidicornis*-type dominate and the presence of *Chironomus anthracinus*-type suggests slightly warmer conditions and more nutrients in the lake. In the next zone (ca. 17–11 ka), *Corynocera ambigua*, a taxon with uncertain distribution in respect to temperature, becomes the dominant chironomid. The relative abundances of *C. ambigua* match the climate variability of the Lateglacial, with peaks corresponding to the cold phases of the Oldest and Younger Dryas interrupted by the warmer Bølling/Allerød. The last zone (ca. 11–9 ka, onset of the Holocene), shows the highest diversity and presence of warm indicative taxa like *Microtendipes pedellus*-type and *Pseudochironomus*. A first attempt of temperature reconstruction using a calibration dataset from Switzerland and Norway suggest temperatures of ca. 13°C in the lowest part of the record, with coldest values (10°C) inferred for the second zone, a time consistent with estimates of maximum extent of northern Alpine glaciers. However, high abundances of *C. ambigua* make the temperature reconstruction challenging for the Lateglacial by giving exceptionally cold values, which does not agree with warmer reconstructions from other palaeoenvironmental archives. Future work will focus on revising the chironomid record and applying calibration datasets with a more realistic (i.e. warmer) distribution of *C. ambigua* to the latest part of the record.

The ecoclimatic gradient from Central Asian larch timberline reproduces pollen-stratigraphical changes in a continuous LGM lake record at the southern Alpine fringe

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During the Last Glacial Maximum (LGM), the southern provenance of moist air masses led to asymmetric ecoclimatic effects on both sides of the Alpine chain. On the northern side, a treeless semiarid foreland was connected to the European Ice Sheet by a continuous loess belt; on the southern side, a mixed coniferous forest steppe persisted throughout the coldest spells. Further south, towards the Adriatic cryptodepression, a continental timberline (sensu Holtmeier, 2009) developed, with the larch forest steppe tapering towards steppe and semidesert megabiomes.

In this work we present quantitative pollen-stratigraphic evidence from the continuous Lake Fimon sequence (northern Italy), together with co-registered sedimentary proxies and modern pollen analogues from the Altai-Sayan Mountains of southern Siberia. We show that their modern ecoclimatic timberline gradient reproduces the pollen-stratigraphic changes observed in our lake record during the Last Glacial Maximum.

The climatic envelope of LGM pollen descriptors shows that the sensitivity of past forest biodiversity to climate changes is driven by the abundance and pollen productivity of W-Eurasian larches (*Larix decidua, L. polonica, L. sukaczewii, L. sibirica*) compared to pines. Furthermore, we avoided harmonization of pine pollen types among fossil spectra and the modern calibration sets, as this depletes the climate sensitivity of pollen analogues. We recall the substantial differences in the ecological envelopes of the pine groups – i.e. the arolla-siberian pine group (*Pinus cembra* and P. *sibirica*), the *P. sylvestris/mugo* group, and of the Mediterranean pines. Pollen spectra dominated by semidesert and steppe treeless vegetation descriptors proved to be less sensitive to changes in thermal continentality. These similarities proved to be statistically robust to the modern analogue technique.

By dating larch charcoal and other terrestrial plant remains we produced a superior-quality radiocarbon chronology, overcoming dating issues typical of mid-latitude treeless biomes.

We recalibrated marine chronologies from the North Atlantic and the Mediterranean using Intcal20 improvements and we compared high resolution marine records with the Lake Fimon pollen record to explore linkages between millennial-scale climate evolution in the North Atlantic and in the Alps during the Last Glacial Maximum and the Alpine Lateglacial (30 to 12 ka).

Last Glacial Maximum to Late Glacial vegetation and landscape history of Central Kamchatka Peninsula (Southwestern Beringia)

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We use a new high-resolution pollen, spore and charcoal record from a former proglacial lake to reconstruct the Last Glacial Maximum (LGM) to Late Glacial (LG) vegetation and landscape history of central Kamchatka Peninsula in the Russian Far East. The paleoenvironmental record, based on a well-resolved radiocarbon chronology, shows a series of millennial-scale changes in the regional landscape that reflect the complex interplay between the planetary radiative forcing and local geomorphological processes. The earliest part of our record (28.4 to 26.3 ka BP) was dominated by a shrubby tundra mosaic interspersed with *Larix* groves and poorly vegetated patches in areas with active fluvio-glacial activity. Between 26.3 and 23 ka BP, open herbaceous habitats expand to the detriment of shrubs. A cryocratic landscape is fully established between 23 and 18.5 ka BP and is characterized by a patchy cold tundra with pioneer/disturbed habitat forbs, graminoids and other herbaceous species. In more sheltered, upland areas small shrubs and isolated *Larix* groves may have been present, while on mesic sites *Populus* was locally abundant. Between 18.5 and 14 ka BP, soil conditions improve, probably under the influence of an increasingly positive planetary radiative balance and lead to the expansion of grasses and, to a lesser extent, tall shrubs. Fire-prone dry grasslands characterize the period between 14 and 12.6 ka BP. From 12.6 to 11.1 ka BP, a period which includes most of the Younger Dryas chronozone (12.8-11.7 ka BP) and the beginning of the Holocene, *Alnus* shrubs expand widely and tree alder (possibly *Alnus hirsuta*) appears in the local vegetation, suggesting an increase in available soil moisture and warmer conditions. A brief re-expansion of grasses (11.1-10.4 ka BP), before the establishment of more typical Early Holocene *Alnus* shrub-fern ecosystems point to unstable climate and landscape conditions during this time. Low but quasi-continuous *Picea* pollen may be evidence of a previously postulated glacial refugium for Kamchatka's enigmatic "conifer island". The aquatic pollen record suggests that the proglacial lake may have had variable water levels before its complete drainage around 12.8 ka BP.

Proxies, models, and people – using transient iTRACE climate models to disentangle proxy and archaeological records during the LGM and deglacial in Australia

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The Last Glacial Maximum (LGM; 21±3ka) has been a focus of Australian palaeoclimate and archaeological research for over half a century. Previous models propose it to be a period of extreme cold and aridity, and that past Aboriginal populations collapsed and retreated into small ecological refuges to survive. This view has become increasingly untenable, with evidence of a longer multi-phase climatic downturn and genomic and archaeological data which does not support societal collapse or widespread abandonment of different regions. Here, we compare transient iTRACE climate models with palaeoclimate proxy records to re-examine Australian LGM and post-glacial climates and compare these with compilations of archaeological dates from the new SahulArch database. Multi-site comparison of continuous proxy records suggest an extended period of extreme conditions existed between 28.3-17.3 ka, which resulted in widespread changing vegetation structures. iTRACE climate model outputs suggest overall cooler conditions (-4–9 °C), but no evidence of substantial precipitation decrease over large parts of the continent. Kernel Density Estimates (KDE) of fluvial and lacustrine OSL and TL ages from the two major drainage basins in central and eastern Australia, the Lake Eyre and Murray Darling basins, indicate continued fluvial activity throughout the LGM period. An active monsoon, lower temperatures and reduced transpiration rates would have resulted in the continued functioning of hydrological systems within the two basins. KDEs of ages (^{14}C, OSL and TL) from archaeological sites show relatively unchanged occupation of landscapes and persistent site use across most regions at the peak LGM and post-glacial period, suggesting widespread abandonment or population collapse did not occur in all arid regions.

Climate sensitivity and ecoclimate sensitivity: inherent tradeoffs and past implications for 21st-century biospheric responses

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Two usages of 'climate sensitivity' co-exist: one climatological, one ecological. The earlier climatological usage quantifies the sensitivity of global mean surface temperatures to atmospheric CO_2, with variants differing by timescale and processes. The ecological usage, renamed as ecoclimate sensitivity, is defined as a change in an ecological response variable per unit climate change. Paleoclimatic data, particularly those for the Last Glacial Maximum (LGM) are widely used to constrain equilibrium climate sensitivity, with estimates narrowing to 2.4 to 4.5°C. By contrast, there have been few explicit efforts to use paleoecological data to constrain ecoclimate sensitivity, but high sensitivity is indicated by widespread post-glacial biome-scale ecosystem transformations, continental-scale species range shifts, and high rates of community turnover. When climate and ecoclimate sensitivity are considered jointly, several points emerge. First, because radiative forcing scales logarithmically to $[CO_2]_{atm}$, ecological impacts per ppm $[CO_2]_{atm}$ often also scale logarithmically, although non-linear ecoclimate sensitivities alter this expectation. Second, there is an inherent tradeoff between past estimates of climate and ecoclimate sensitivity, because, for any given past observed ecological event, a smaller climate sensitivity estimates directly imply higher ecoclimate sensitivities. For example, a low-end estimate of climate sensitivity for the LGM (e.g. 2.4°C) would imply a much ecoclimate sensitivity of species and ecosystems. Given past biospheric transformations, we can expect high sensitivity of the terrestrial biosphere to current rises in $[CO_2]_{atm}$, a conclusion that is insensitive to climate sensitivity. Third, biological proxies remain a backbone of climate sensitivity estimates, so to avoid circularity, proxy networks used to constrain climate and ecoclimate sensitivity must be carefully separated. Given the equal importance of climate and ecoclimate sensitivity, equal effort must be devoted to constraining them. Hence, as estimates of climate sensitivity narrow, a critical priority going forward is to assemble networks of paleoclimatic and paleoecological proxies and models to better quantify the processes governing the form and variations of ecoclimate sensitivity across systems and scales.

Session 14: Climate and environmental changes during the Holocene and past interglacials based on biological and geochemical proxies

A Holocene branched glycerol dialkyl glycerol tetraether (brGDGT) record from the high altitude lake Garba Guracha, Ethiopia

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The spatially complex climate variability in eastern Africa and the associated driving mechanisms during the last 15,000 years are not yet fully understood. In particular, a lack of paleoclimatic studies from the Horn of Africa prevents a broader spatial understanding of climatic changes in eastern Africa. Therefore, we seek to calibrate and apply new organic geochemical biomarker proxies for temperature in this region, specifically branched glycerol dialkyl glycerol tetraethers (brGDGTs).

In the surface sediments of Bale Mountain lakes in Ethiopia, Horn of Africa, we found a unique abundance of 6-methyl brGDGT isomers, compared to similar eastern African lakes (Loomis et al., 2012; Russell et al., 2018), possibly influenced by the water chemistry of the lake or by changes in the bacterial community. Therefore, we developed a new local brGDGT temperature calibration that also accounts for 6-methyl isomers. We reconstructed Holocene mean annual temperatures based on brGDGTs and analyzed δ^2H of *n*-alkanes extracted from a 1550 cm (~ 16 ka) lake sediment core from high-altitude cirque lake Garba Guracha in the Bale Mountains.

Reconstructed annual mean temperatures (n=35, 4-10°C) indicate that colder conditions prevailed in the high elevation Bale Mountain ecosystem during the Younger Dryas. In addition, we reconstructed a delayed response to the northern hemisphere summer insolation maximum during the Late Glacial and a thermal optimum in the mid-Holocene that coincides with the September insolation maximum at 6°N. Reconstructed δ^2H values, often interpreted as a proxy for precipitation amount or source, show a strong similarities between low-latitude archives in eastern Africa and suggest meridional driven climatic changes during the Holocene rather than an east-west influence.

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Holocene environmental history recovered by high resolution hyperspectral imaging and XRF elemental data

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The sediments of Holzmaar (West-Eifel Volcanic Field, Germany) provide one of the best studied Holocene and Late-Glacial varve records worldwide. However, past publications about this sedimentary record focused mostly on certain time windows and presented data with centennial or sub-decadal temporal resolution. We recovered new sediment cores from Holzmaar in 2019 and applied scanning techniques with high µm-scale spatial resolution to study depositional changes with annual to sub-annual temporal resolution. The existing varve chronology was transferred and updated to the new composite sediment record by applying Bayesian modelling. This chronology enables us to scan the sediment sequence with X-ray fluorescence and hyper spectral imaging and interpret the obtained datasets for the entire Holocene record with up to seasonal resolution. By applying statistical and machine learning techniques (e.g. principal component analysis, CONISS clustering, recurrence plots), we obtain a thorough picture of trends as well as periodic and abrupt changes in sedimentation. How these are linked to external and internal forcing factors, which in turn are related to catchment and lacustrine processes, will be unraveled. By considering all available information, we delineate our findings in a conceptual model for selected periods of the lake's Holocene history.

Unravelling Surface UV-B Variations across the Maunder Minimum and Satellite Era using Sporomorph Chemistry

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Solar UV-B radiation is harmful to the biosphere. Prolonged, unprotected exposure to UV-B damages the DNA in skin cells which can be detrimental for humans and animals alike. Plant growth and reproduction can also be negatively impacted by exposure to UV-B radiation. Understanding patterns in the past, present and future flux of UV-B radiation is therefore of crucial interest.

Anthropogenic release of ozone-depleting gases can cause surface UV-B fluctuations, however, natural processes including solar activity, stratospheric volcanic eruptions, geomagnetic field variations, and orbitally influenced variations in insolation also result in ozone perturbation and hence surface UV-B variations. Therefore, to fully assess human influence on ozone, we need to better understand how surface UV-B has varied prior to the industrial and pre-instrumental era. At present, UV-B and ozone measurements are made through satellite observations and ground-based sensing. As these measurements only cover the instrumental era, proxies are needed to reconstruct pre-instrumental variations.

Chemical analysis of sporomorphs is an emerging proxy for surface UV-B levels over geological timescales. Plants increase levels of UV-B absorbing compounds (UACs) (e.g. ferulic acid and *para*-coumaric acids) in their sporomorphs in response to increases in UV-B radiation. Sporopollenin, the exine of sporomorphs is chemically inert, preserving UAC levels over millennia after deposition under anaerobic conditions. This allows preinstrumental UV-B variations to be inferred from measurements of UACs in sporomorphs.

In this work, we utilise Micro Fourier Transform Infrared Spectroscopy (Micro-FTIR) to measure UAC content of pollen grains from lake sediments of Nar Gölü (Turkiye), expanding on similar previous work at that site. We produce a high-resolution UAC record for the Maunder Minimum (1645 – 1710 CE) and satellite era (1977–2010 CE). Comparisons against modelled UV-B and satellite UV-B data, respectively, will be used as a measure of confidence in the UAC records for determining higher resolution patterns of UV-B variation than have hitherto been produced. We also hope to address key questions around relationships between solar activity and surface UV-B receipts. For example, is the apparent cessation in the 11-year solar cycle during the Maunder Minimum as evidenced by sunspots also reflected in surface UV-B receipts?

Linking pollen types to plant taxa – modelling Holocene regional ecological and climate shifts for the Central Sahara.

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Pollen analyses from sediments of the (Central) Sahara document distinct palaeoecological fluctuations during the Holocene. However, the reconstruction of ecological successions remains challenging, because linking of plant species to pollen-types often is restricted on few, selective plant species or genera and may lead to distorted results. We thus established an advanced pollen type – plant taxa assignment based on available publications and databases on pollen morphology of the respective plant species, tribes, genera etc., in order to get a more objective, reproducible interpretation of the pollen spectra.

This assignment of plant taxa to pollen-types builds the basis for a quantified reconstruction of the ecological and climatic shifts during the Holocene in the Central Sahara, based on pollen spectra out of a 16 m long lake sediment core, deposited continuously during the last 10500 years in the Lake Yoa, Ounianga basin, Chad. The pollen-based proxies are compared to delta 18O-measurements on sedimentary carbonate.

In a following procedure the pollen-types plant species assignments are applied to published pollen spectra available for the (Central) Sahara, allowing reproducible standardized, synthetic reconstruction of Holocene ecological shifts. The regional variability of past ecological responses also inform about ecological response ranges in regard of ongoing and future climate changes.

Development of the Nile Littoral Cell during the past 8.2 kyr

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The history of the Nile Littoral Cell (NLC) in the past ~8 kyr BP was constructed from radiocarbon-dated cores retrieved down-flow the Nile Delta. Grain-size distribution, chemical composition, and Nd-Sr isotopic ratios together with marine derived variables as carbonate content, total organic carbon and its isotopic carbon composition record the variations in transport processes and sediment provenance. From 8.2 to 5.5 kyr BP the record is dominated by quartz sands from the Nile Delta that were recycled due to shelf transgression at the final post glacial sea level rise. Oligotrophic conditions prevailed in the shelf, and the relatively high carbonate content reflects the decrease in Nilotic fines due to increased vegetation and decrease in surface erosion related to the African Humid Period (AHP) wetter conditions. The geochemical signature of the fines represent mostly remobilization of aeolian sediments from the surrounding deserts by the increased runoff. Sea level stabilization, termination of the AHP and the drying of the Ethiopian Highlands resulted in the increase of sediments with a basaltic signature. After ~5.5 kyr BP, fine sediments were supplied seasonally by the Nile, increasing water column productivity and creating a distinct mud belt at water depth exceeding ~35m. Occasional sediment coarsening in the distal NLC likely reflects periodical decrease in Nile floods discharge or contribution from shallower water depth due to increased storminess. With the continuation of the regional aridification and decreasing of the Nile River flow in the last 3 kyr, contribution of dust particles from the nearby lands was recorded in the distal NLC, while the proximal cell continued to be affected mostly by the Nile. A distinct increase in grain size and carbonate content, decrease in TOC content at the topmost part of the record represent the Nile damming in the modern period, which resulted in halting of the seasonal floods suspension.

Responses of sedimentary proxy to hydrological and climatic changes in a maar lake situated at the southern margins of Arabian desert

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Lake sedimentary records from the southern Arabian Desert are scarce. Thus, documentation of the distinct climatic and environmental shifts based on these archives for the mid-late Holocene is of utmost importance. This project aims to identify the onset and periodicities of climatic events based on a reliable interpretation of a set of proxies applied to a lake record from Yemen.

A composite ~1 m long core (JAS) was recovered from the maar lake Karif Shawran, southern Yemen. Geochemical, mineralogical and biological proxies were applied on the JAS core for reconstructing past global changes and providing information on the surrounding terrestrial environment and climate history. The chronology presented here is based on four radiocarbon ages derived from ostracod shells that reach ~3800 yr BP. The lithology of the JAS core consists of lamina-scale alternations of halite and organic detritus layers with an average thickness of 1-3 mm. Moreover, our study reveals turbidite and ash layers within the laminated sequence. Furthermore, XRF data revealed increased physical weathering, marked by higher K/Ti values and lower Ca and Fe normalized count, pointing to high lake-level stands. In contrast, intervals of low lake-level were marked by decreased physical weathering and increased authigenic precipitation of halite crystals coupled with higher levels of Ca and Fe normalized counts. This inference is also supported by a correspondence between lower magnetic susceptibility due to wet/humid conditions with higher levels of total organic carbon and vice-versa. The *n*-alkanes proxies like P_{aq} were generally low, indicating increased aquatic macrophytes in response to lake-level drop due to arid conditions. The ostracod assemblage data suggests the presence of a single euryhaline species *Cyprideis torosa*. Ecophenotypic variation of *C. torosa* valves provided some useful paleolimnological information, such as the variability of salinity ranges in the lake water. These, in turn serve as a linkage to paleoclimatic and paleoenvironmental changes. Overall, this study provides information on the major driving factor behind the hydroclimatic shifts in the region and helps to understand the role of the ITCZ vis-à-vis monsoonal dynamics. Moreover, it develops the initial understanding of long-term strategies in the seasonal prediction for Southern Arabia.

Coral geochemical records as tracers of ecosystem change in the Tropical Eastern Pacific over the late-Holocene

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Along the coast of the Tropical Eastern Pacific (TEP), regions of strong seasonal upwelling bring cold, nutrient-rich deep waters into coastal zones, controlling ecological conditions and sustaining millions of people through the production of large-scale fisheries biomass. The TEP is also important for the regulation of global climate and is affected by large-scale processes such as ENSO. How the nutrient dynamics of this region will respond to future climate change and what the implications will be for coastal ecology and human livelihood are critical to know for environmental research, but remains to be studied. Environmental records are needed that capture intra and inter-decadal variation and extend back into millennial time scales where these biotic and abiotic processes play out. To address this, we developed a new sampling approach and constructed two records produced from coral skeletons (n = >600) collected in reef matrix cores and extending over six millennia from the upwelling Gulf of Panamá and the non-upwelling Gulf of Chiriquí. We ask what effects millennial-scale climate patterns have on seasonal upwelling in the region, and how the magnitude of upwelled nutrients influences ecological productivity and even implications for human habitation. To investigate this question, we combined multiple proxies using climatic (carbonate $\delta^{18}O$), nutrient (skeletal-organic matrix $\delta^{15}N$), diagenetic (taphonomic scoring), ecological (benthic community composition), and temporal (U-Th dates) data. Using a Generalised Additive Model-based approach for assessing data variability, we find strong divergences in the nutrient ($\delta^{15}N$; range >5 ‰) records between Gulfs, while $\delta^{18}O$ (range ~2‰) appears more stable. The greatest variation in $\delta^{15}N$ values occurs during times of high reef accretion whereas $\delta^{18}O$ remains constant, suggesting that nutrients, not temperature, are driving reef productivity. Taphonomic, taxonomic, and age models reveal periodic shifts and/or collapses of coral communities that differ between Gulfs. We end by drawing connections between these ecological shifts to the episodic human habitation documented in the region during the late-Holocene, and hypothesize what this may mean under future climate conditions.

Holocene Indian summer monsoon variability in the Northeastern Indian Ocean

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The Indian Summer Monsoon (ISM) is a significant water source for India. Recent studies showed an increasing trend of spatial and temporal variability of rainfall extremes in India owing to the consequences of climate change. The Holocene period has witnessed several climatic perturbations and coincided with the disruption of major civilizations illustrating the human significance of the Holocene climate variability. Recently occurred monsoon-related catastrophic events have urged the importance of understanding the centennial-millennial-scale ISM variabilities in the immediate past, thereby developing reliable predictions for future variations. A better understanding of ISM's timing, magnitude, nature, and forcing mechanisms during the Holocene is vital to portray future manifestations in the present climate change scenario. The Holocene ISM reconstruction varies substantially across different regions and shows large-magnitude fluctuations over the millennial timescale. The intensification of ISM during the Holocene commenced at the beginning of the early Holocene (11.4 ka) with a stepwise increase at 10.6, 9.3, and 8.0 ka. A short period of weak ISM is identified at 8.5 ka, marked changes in the salinity-sensitive foraminiferal proxies, which broadly corresponds to the 8.2 ka cooling event observed in the Greenland ice cores. Weakened ISM during this period is also reflected by increased productivity driven by wind-induced mixing when the upper water column was less stratified. ISM was also stronger during the early mid-Holocene (8.2 to 7.2 and 7.0 to 5.5 ka) and late Holocene (3.5 to 2.2 ka and 2.1 to 1.1 ka). A progressive decline in the abundances of productivity and salinity proxies from 4.2 to 2.0 cal ka suggests a gradual weakening of the ISM during the late Holocene. During the recent cold period, the Little Ice Age, ISM shows alternate strong and weak phases. ISM also shows large spatial variability, with northern part records showing maximum ISM precipitation occurred during the mid-Holocene. In contrast, southern Andaman Sea records show the strongest Holocene monsoon signal during the early Holocene. A systematic assessment of precipitation records based on proxies that track freshwater input and runoff was presented to better understand the spatiotemporal nature of its maximum precipitation during Holocene.

Interglacials of Middle-Late Pleistocene and Holocene in the northwest North Atlantic

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At high latitudes of the Northern Hemisphere, Quaternary interglacials were characterized by relatively warm conditions but sea-ice, at least seasonal, and some land-ice, notably over Greenland, remained resilient features. This is documented by paleoclimatic and paleoceanographic records from the northwest North Atlantic area that illustrate the interplay of climate, ice, and ocean in response to the large amplitude climatic shifts of glacial/interglacial oscillations. These records also illustrate large-scale instabilities of the Greenland ice sheet. We illustrate these features based on isotopic, sedimentological, and palynological data from marine sediment cores of ODP site 646, IODP site U1302/03, and U1305, from the Labrador Sea.

Pollen and dinocyst records illustrate the uniqueness of each interglacial, and the high amplitude variations of sub-millennial pacing, during most of them, pointing to regional climate instabilities. The overall results also show that ice-rafting deposition occurred throughout most of the middle-late Pleistocene and Holocene, including interglacials, except the marine isotope stage (MIS) 11. A particularity of the regional records is the low sea-surface salinity during almost all interglacials, again with the exception of MIS 11. In the context of the Labrador Sea, low salinity can be associated with meltwater discharges and/or the export of Arctic waters. The last deglaciation and subsequent Holocene sequence in several marine cores of the area indicate that thermal maximum conditions matched particularly low salinity conditions, linked to the final melting stages of the Laurentide ice sheet, whereas the Greenland ice sheet receded to its latest minimal extent. Hence, the combination of low surface salinity and ice-rafting that characterized most interglacials in the Labrador Sea suggests that ice has remained an important component of the regional climate, which might also explain the high-frequency instabilities recorded in sea-surface conditions. From this point of view, MIS 11 stands out as the only “true interglacial” at the regional scale, without sea ice nor meltwater discharge evidence. Although a much-reduced Greenland ice volume likely characterized the MIS 11, there is no evidence of warmer-than-present conditions in the Labrador Sea during this interval. MIS 11 experienced a climate state distinct from that of any other middle-late Pleistocene interglacial.

Investigating the cause and structure of abrupt climate change events during MIS 11c

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Marine Oxygen Isotope Stage (MIS) 11c (~ 424 – 394 ka) stands out as; 1) an orbitally similar period to the Holocene 2) a time of significant Greenland Ice Sheet (GIS) loss. As the GIS is poised to retreat, understanding the impact this could have on North Atlantic dynamics is of paramount importance.

The tephra layer identified by Candy *et al.*, (2021) linking Marks Tey (MT) (Essex) and ODP 980 (Rockall Trough) makes it possible to investigate relationships between marine and terrestrial changes during MIS 11c. The tephra layer in the varved sediments at MT occurs just prior to an isotopic event, culminating in a ~ 500 yr ecological response. Simultaneously, there is a reduction in Sea Surface Temperatures (SSTs) at ODP 980, indicated by an increase in *N.pachyderma* ~ 415 ka. The aim of this study is to make use of the MT sequence in conjunction with a series of ocean cores to investigate this pre-Holocene Abrupt Climate Event (ACE).

We make use grain size analysis, Ice Rafted Debris (IRD) and foram-census data at 6 North Atlantic sites: IODP U1302 and U1305 (Labrador Sea / Denmark Strait Overflow Water (DSOW)); ODP 983, 984, and IODP U1304 (Iceland Scotland Overflow Water (ISOW)), and ODP 980. MT sediments have been sampled for biomarkers and isotopes to examine the on-shore environmental signal of this event. At MT, results confirm a long-term cooling trend spanning ~ 1500 varve years, punctuated by repeated isotopic incursions prior to/culminating in the ecological response. Ocean data indicates SST cooling event at all sites concurrent with a reduction in current flow strength at all sites except U1304. Each of these sites share common features: (1) being during the first phase of MIS 11c (424 – 410 ka) (2) after the final cessation of IRD (~ 419 ka onwards) (3) ~ 1500 years in duration. Despite chronological issues, it is likely these are concurrent, indicating a pan-North Atlantic cooling event with an ecological response. This is the first study to be able to produce such a high-resolution record of a pre-Holocene ACE.

Multiproxy investigations reveal the environmental succession of the oldest interglacial (MIS 11) detected for the crater infill of Rodderberg, Germany

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Interglacials are of increasing interest for Quaternary science because they provide information about natural interactions between climate and ecosystems for conditions comparable to the Holocene as well as for climate projections of the warmer future – but without any human influences. Thus, they are past analogues to constrain impacts and dynamics of the ongoing global warming. To tackle these scientific challenges, we are studying the sedimentary infill of Rodderberg, a silted-up volcanic crater in the immediate vicinity of the city of Bonn in western Germany. The depositional succession encounters lacustrine sediments at the base, loess (partly reworked) in the central part and a Holocene luvisol at the top. Altogether, this sediment sequence covers several glacial-interglacial cycles in superposition, which characterize the depositional record of Rodderberg as a rare and promising environmental archive. The first and most challenging task for our investigations is to establish a robust chronology. For this purpose, we combine radiocarbon and luminescence dating with volcanic ash layers and pollen biostratigraphy to establish the timescale. Based on reconstructed vegetation assemblages and successions for the most pronounced and oldest interglacial of the sediment sequence, the oldest Rodderberg interglacial tentatively dates to 380-430 ka, which chronologically relates to Marine Isotope Stage 11 (MIS 11). This timing is supported by a dated tephra layer deposited during the early temperate phase of this interglacial. Thus, the eruption of the Rodderberg volcanic complex itself dates to glacial conditions before this volcanic eruption, i.e. prior to ca. 430 ka (MIS 12).

Preliminary diatom data provide information about the development of the local lacustrine system, while pollen and stable isotopes of carbonates and bulk organic matter reflect environmental changes of the catchment area. This data is supported by bulk geochemistry as well as by sub-centimetre scale elemental data obtained by XRF scanning. Together, this will provide a holistic view of environmental reactions and their biogeochemical responses triggered by climatic changes as archived by the depositional system of the Rodderberg crater lake during Middle Pleistocene interglacial conditions.

Common characteristics and differences of past and present interglacials in NW Europe: combining malacology and geochemistry

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NW European valleys are characterised by stepped systems, within which terrace incision and sediment deposition are strongly controlled by climatic cycles. Temperate periods are represented by fine-grained fluvial sediments but malacological studies have demonstrated that full interglacial conditions are registered only in tufa formations at the top of the sedimentary series. Calcareous tufas contain diversified fossils and are particularly favourable for the preservation of rich molluscan communities allowing detailed palaeoenvironmental reconstructions. Besides, geochemical analyses on tufa calcite provide high quality palaeoclimatic information. Multiproxy studies of NW European tufa deposits dated from MIS 11c, MIS 5e and the Holocene have been developed in the last decade allowing the reconstruction of both climate and environment dynamics during those interglacials. The recolonization of forest land snails is shown to follow a pattern common to all the studied interglacials and correlates with increasing temperature and moisture. The order of appearance of species, depending on their ecological tolerance, is linked to temperature increase. The maximal diversity and richness of forest land snails correlates with the thermal optimum and high moisture values in the isotopic data. The latter part of interglacial tufas is characterized by the decline of forest land snails and a marked decrease in temperature.

Beyond this general scheme, differences between interglacials are observed with respect to the presence of extinct taxa and/or species out of their modern range identified as “malacological signatures”. Pleistocene series hold richer communities with numerous central and eastern European current species, whereas Holocene assemblages are characterized by species with mostly western and northern European modern ranges. Comparison of associated isotopic data shows that Pleistocene interglacials, and especially their optima, appear stronger than the Holocene: MIS 11c was wetter and warmer and MIS 5e, experienced wetter conditions than the Holocene. Additionally, investigations on Holocene tufas across temperate Europe show a pronounced decreasing gradient in richness of forest species from east to west while moisture conditions reconstructed from isotopic analyses are higher in the western locations compared with eastern sequences. This demonstrate that beyond climatic conditions, colonisation dynamic of living organisms can also be strongly dependent on distance from refugia.

Palynological analysis of the MIS 11 interglacial from a sediment succession from Fucino Basin, Italy.

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There are large gaps in our understanding of how the global water cycle and ecosystems will respond to future global warming. The study of sedimentary records can give us insight into climatic patterns in the past, how ecosystems adapted to warmer temperature conditions, and could serve as analogues for future global warming. The Marine Isotope Stage (MIS) 11c (ca. 426-396 ka) arises as one of the anomalously long and warm interglacials of the past 800 ka, with a global temperature ca. 0.5-0.7 ºC higher and a relative sea level of ca. 6-13 m higher than the pre-industrial Holocene, respectively. The Fucino Basin (Central Italy) contains a continuous lacustrine succession for the last 430 ka including MIS 11, dated by tephrochronology. Paleopalynology can be very useful as an environmental and paleoclimatic tool, through observing the changes in vegetation caused by temperature and precipitation changes. In this study, we present the preliminary results of the pollen analyses of the Fucino sedimentary succession between MIS 11c and the glacial termination V (glacial-interglacial transition between MIS 12 and MIS 11) to reconstruct the environmental change during this period. Our results show that an increase in humidity at the start of the MIS 11c interglacial the Fucino Basin, which is indicated by the exponential growth of the *Abies* population. Also, the generally warm interglacial was characterized by millennial-scale climate variability with several periods when the temperature decreased and the aridity increased, as testified by the *Abies* population decreasing and the *Poaceae*, *Artemisia*, *Amaranthaceae*, *Hippophae*, *Ephedra* and *Pinus* association increasing. The Fucino Basin lacustrine pollen record can provide us with a very accurate vision of the response of the vegetation during a period warmer than pre-industrial Holocene, thus arising as a potential reference fossil scenario that allows us evaluating the potential ecosystem impact of the current anthropogenic global warming.

Detailed record of interglacial palaeoclimates and palaeoenvironments in Northern France calcareous tufas: new data from the sequence of Resson (Eemian) and comparison with the MIS 11c and the Holocene

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Detailed continental records of past interglacials where both palaeoenvironnemental and paleoclimatic reconstructions can be achieved are scarce in NW Europe. In this context, calcareous tufas are generally the only sedimentary records of Pleistocene interglacial optima. They are thus key-archives to investigate climate-environment interactions during interglacials for they contain abundant flora and fauna remains (especially molluscs) and their calcite composition allows direct dating as well as geochemical reconstructions of palaeoclimatic parameters. During the last two decades, multiproxy investigations of tufa deposits from northern France, including Caours (Somme basin, MIS 5e) et La Celle (Seine valley, MIS 11c), have provided detailed records of climatic and environmental changes during past interglacials and allowed comparisons with the Holocene.

In the Seine basin, the large tufa deposit of Resson has recently provided the opportunity to expand the record of Eemian environments and climates in the area. The site delivered in the 19th century a rich content in macroflora and large mammal fossils but was little investigated since. New fieldworks involving a multidisciplinary research team have allowed to describe and sample an extended section (>20 m long) of the Resson tufa. The entire 10m-thick sequence was sampled continuously and in parallel for malacology and isotopic geochemistry. Preliminary mollusc data indicate a high richness, especially in the number of both land snails and forest species and document the progressive development of interglacial conditions. Calcite stable isotopes provide a consistent record, showing a regular increase in humidity ($\delta^{13}C$) and warm conditions ($\delta^{18}O$), reaching an optimum in the upper part of the sequence. Compared to Caours palaeoenvironmental and palaeoclimatic reconstructions, where the optimum is strongly marked at the very bottom of the tufa sequence, Resson provides a more dilated record of the progressive establishment of wet and temperate conditions during the early phase of the Last Interglacial. Comparisons with data from tufas assigned to other interglacials from the same area confirm that the Eemian optimum, just as the MIS 11c, was significantly wetter than the Atlantic period while no strong differences are observed between Eemian and Holocene temperatures.

Palynology, palaeoclimate and chronology from the Saalian Glacial and the Saint-Germain II interglacial from two long cores in the Sea of Marmara

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The Marmara region (NW Turkey) has a transitional vegetation and climate between Mediterranean and Euxinian. For the last Interglacial period and the following two Saint-Germain Interstadials, no information is available yet. Here we provide the results of the pollen analysis of two sediment cores taken from the Sea of Marmara. We focus on the period below the red-H1 seismic horizon, which corresponds to the last interglacial and a large part of the previous glacial period. A pollen-inferred palaeoclimatic reconstruction is proposed based on the MAT method.

Based on geochemistry that allows inter-core comparison and on a succession of warm and cold phases derived by pollen analysis, a nearly complete sequence from the Saalian Glacial period to the Saint-Germain II Interstadial was obtained, despite the occurrence of hiatuses corresponding often to lowstands.

The *Pterocarya* extinction has been traced from MIS 11 in Italy to Saint-Germain I Interstadial (c. MIS 5c) in the eastern Sea of Marmara, showing a progressive retreat from west to east until the Black Sea region where it is still present nowadays.

Climatic quantification, by the MAT method, indicates warmer temperature and a slightly drier climate than at present, at its peak of the Eemian. This is reflecting a shift of the Mediterranean climate to the NE and a reduction of the Euxinian vegetation.

A history of fire in eastern Australia over two interglacials: one without and one with people

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Ethnographic observations suggest that Indigenous people employed a distinct regime of frequent, low-intensity fires in the Australian landscape. However, the timing of this and the ecological impact remains contested. Here, we present detailed analysis of charcoal, including for the first time, a measure of fire severity using Fourier Transform Infrared (FTIR) spectroscopy, at a site in eastern Australia that spans the last two interglacials and their late glacial transitions (between 135-104 and 18-0 cal years BP, broadly equivalent to Marine Isotope Stage (MIS) 6-5 and 2-1, respectively).

The accumulation of charcoal and vegetation composition (from palynology) was broadly similar across both periods, and trends and patterns correlate loosely with Antarctic ice core records (dD). This suggests that climate was a significant driver of fire at the site through both periods. We also found that fire was a distinct feature during these glacial terminations.

Fire severity was mostly lower over the last 17,000 years compared to the penultimate transition and interglacial (MIS 6-5) and this may reflect anthropogenic management of the landscape. We highlight that this signal is not easily discernible in the other proxies examined, including widely used charcoal methods, and propose that any anthropogenic signal is likely to be subtle in the palaeoenvironmental record – reflective of a regular, low severity fire regime. This record does however represent one of the few unequivocal records of the impact of Indigenous people on the fire regimes of Australia.

Insights into the Nature of Climate Variability During the Last Interglacial: A High-Resolution Multi-Proxy Record from the Fucino Basin, Central Italy

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Environmental reconstructions of the Last Interglacial (LIG, 129-116 ka) can enhance knowledge of natural climate variability under conditions of excess warmth. The LIG was characterised by a global mean temperature ~0.8˚C warmer than the pre-industrial era, pronounced Arctic warming, and elevated sea level (~6-9 m above present). Exploring the local expression of LIG climatic changes through vegetation dynamics using combined pollen and stable isotope analyses can strengthen understanding of regional responses to a warmer background state. However, a lack of high-resolution palaeoclimatic archives employing a precise, independent, and robust chronological framework remains a primary limitation in investigating LIG climate variability and relating it to changes in other records.

Here, we present detailed palynological, charcoal, geochemical and isotope analyses of a thick lacustrine sedimentary sequence retrieved from the Fucino Basin, central Italy, covering the period from 139 to 107 ka. A crucial aspect of the record is its independent chronology based on direct $^{40}Ar/^{39}Ar$ dating and geochemical fingerprinting of several tephra layers. Pollen and charcoal analyses were conducted at 4 cm intervals representing a sampling resolution of ~80-100 years. Stable isotopic analyses ($\delta^{18}O$ and $\delta^{13}C$) were undertaken on lake carbonates every ~8 cm (~180 years). Annual and seasonal temperature and precipitation was reconstructed from fossil pollen assemblages as a consensus of three different models (WA.m, TWAPLS and BUMPER).

Multi-proxy analyses capture environmental responses to long-term and short-term climatic variability during the LIG at Fucino Basin. The detailed pollen sequence reveals a succession of arboreal phases, interrupted by a series of centennial- to millennial-scale contractions in temperate vegetation. Pollen-based climate reconstructions infer an overall warm and wet climate with peak annual temperatures ca. 2˚C warmer than present day. Comparisons between $\delta^{18}O$ records from the Fucino Basin and an Italian stalagmite (Corchia Cave) suggests a strong hydrological seasonal contrast during the early LIG corroborated by increased Mediterranean taxa abundance and elevated fire activity. The early LIG in Italy emerges as a time of high seasonality with arid summers and enhanced winter precipitation driven by strong Northern Hemisphere summer insolation.

High-resolution environmental and climate variability during the penultimate glacial and the Last Interglacial in the Padul wetland, western Mediterranean region.

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The study of past climate periods, similar to the present, is very important to understand how the environments will respond to the rising global temperatures. The Last Interglacial (LIG) warm period, also called Eemian and corresponding to Marine Isotope Stage 5e (~130-115 kyr), is commonly used as a reference for a projected future climate. There are not many long and continuous sedimentary records in sensitive areas as the Mediterranean region where this period is registered. In fact, seasonal characteristics of interglacial climate dynamics are still unknown in this area. The Padul sedimentary sequence provides exceptional paleoenvironmental and paleoclimate information of the last ~200 kyr from the southern Iberian Peninsula. Here we present a detailed palynological study to contribute new insights into vegetation changes in order to infer precipitation and temperature shifts in the western Mediterranean area before, during and subsequently after the Last Interglacial. The preliminary results indicate that the termination of the penultimate glacial was the coldest and driest climatic phase, shown by the maxima in xerophytes (*Artemisia,* Amaranthaceae *and Ephedra*) and minima in Mediterranean forest (*Quercus* total, Oleaceae and *Pistacia*). The beginning of the LIG is characterized by an abrupt decline in xerophytes and an increase in arboreal taxa, especially in Mediterranean forest and conifers, indicating an important change towards an increase in temperature and precipitation. However, it seems that this environmental change was gradual in the Padul wetland as suggested by the general increasing trend in the Mediterranean forest. Millennial-scale variability, observed through periodic increases in xerophytes, also characterized the glacial-interglacial transition and the LIG.

The Last Interglacial and the Eemian in the N-Adriatic region: new insights from an expanded microbotanical record of the Coastal Istria (Croatia)

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Here we present the detailed microbotanical study of a 120m-long marine-to-alluvial core MIR1 from the N-Adriatic, which includes a complete Last Interglacial (LIG; ca. 129 to 116 ka) and Eemian (ca. 126-110 ka), providing evidence for centennial-scale events.

The drilling site is located onshore at the mouth of the Mirna River's karst valley, dissecting the outer Istrian limestone plateau, that turned into *rias* during the last two marine high-stands. The most complete transgression sequence, documented between ca. 45 to 75 m of depth, contains an expanded, shallow marine record of the LIG, holding an exceptional potential of co-registered continental and marine biological proxies. We analysed sedimentary and micro-botanical proxies, besides charcoal fragments concentrations as a proxy for fire history.

Vegetation history is marked by a transition from semi-desert and forest-steppe to mixed deciduous-conifer forests during Termination II. A first sharp expansion of deciduous oaks (*Quercus robur* & *Q. cerris* types) is tied to the onset of the penultimate late glacial interstadial, currently dated at ca 132 ka as documented in the $\delta^{18}O$ Corchia Cave record. LIG onset is marked by a second, major step of oaks expansion at ca 129 ka with the development of a typical southern European forest succession, punctuated by events of fire and of moderate forest withdrawal. We propose to tie the first of these events to the sub-millennial C27 cold event at 127 ka. The second part of the temperate phase is considered a post-interglacial Eemian, showing a major turnover in forest composition. Deciduous oaks are gradually replaced by other broad-leaved trees (e.g., *Carpinus betulus*, *Ulmus*), also hosting moisture-demanding species (*Fagus*), and by evergreen Mediterranean sclerophylls (*Phillyrea*, *Olea* and evergreen oaks). Interestingly, the second phase of the Eemian temperate forest is characterized by lower charcoal abundances, compared to full Interglacial conditions and to the Termination II.

The warm-temperate trees are replaced by *Pinus* and *Artemisia*, pointing to the development of forest steppe and semideserts of cold/dry conditions.

Furthermore, we correlated MIR1 with other series from Mediterranean area to compare the ecological record and to distinguish the effect of climatic events at local to global scales.

A not so warm Last Interglacial Period in the SW Pacific, evidence from new dinocyst records

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The Last Interglacial period (LIG) (~130-115 ka) has been the focus of international research interest over the last few decades as its study (either proxy-based or modelling) underlines temperatures globally warmer by 2 to 3 degrees C and a sea level 6 to 9 m higher than present-day. Because these conditions may represent the likely increase in oceanic temperature (~0.6 to 2°C) in the next 85 years as forecast by the latest IPCC scenarios in 2013, it is therefore crucial that LIG climatic variability and its regional expression are understood. Whereas the Atlantic Ocean has been well studied, the SW Pacific Ocean yields sparse records of past LIG conditions. Annual sea-surface temperatures have been estimated in this region for the LIG time-slices using foraminiferal assemblages, and there are a handful of core sites in the region where SST has been estimated using other proxies. To support and test this previous work, the aim is to produce maps of LIG time-slices of annual and seasonal sea-surface temperature (SST), salinity (SSS) and marine productivity, from 55° south to 25° south, over a 40° east-west gradient. To this end, dinoflagellate cyst assemblages from a number of cores, collected east and west of New-Zealand (NZ), are being studied and the Holocene and the LIG records compared. Results show contrasting results with overall annual SST anomalies of the interval 115-130 ka (compared to today conditions) being negative in the north and west, and positive in the east of NZ. Annual SST at 125 ka are overall cooler than present-day, with a maximum of cooling up to about 3°C north of NZ. These new results are comparable to the trends observed by planktonic foraminiferal assemblages, although dinocyst-based SSTs are systematically cooler.

Proxy-based quantitative reconstructions of Eemian climate, Garwolin Plain (Central Poland)

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Three pollen sequences from fossil lakes in Central Poland were used to reconstruct the total annual precipitation and mean annual temperature, as well as the mean temperatures of the warmest and coldest months during the Eemian (Marine Isotope Stage 5e) interglacial.

High resolution pollen data from the Struga (profiles St-19 and G-120) and Parysow (profile Pa-19) sites recorded all seven regional pollen assemblage zones (RPAZs) typical for the interglacial in the European Plain. The modern analogue technique based (PPPbase software) reconstructions were linked with the presence of climate sensitive pollen and plant macrofossil indicator taxa in order to obtain a deeper insight into past climate changes.

The temperature dynamics during the climate optimum (E3-E5 RPAZs) of the Eemian Interglacial were of special interest. The highest mean July temperature (+21°C) was estimated based on the presence of Tilia tomentosa in the E4-E5 RPAZs. The highest precipitation totals were confirmed for the hazel phase (E4), which was not only the warmest period, but the most humid as well. A drop in precipitation and temperature occurred during the decline of the following hornbeam phase (E5), which was one of the possible reasons for the marked lowering of the water level in the Parysow lake and its transformation into a peatbog. The terminocratic parts of the Eemian Interglacial (fir-spruce and pine phases, E6 and E7 RPAZs respectively) are characterized by decreasing temperatures, particularly during the coldest month, and rising water levels due to a combination of decreased evaporation and higher air humidity during the transition to glacial conditions.
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Deglacial increase of seasonality and associated ecological responses in the tropical North Atlantic revealed in varved sediments of the Cariaco Basin

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The varved sediments from the Cariaco Basin, off Venezuela, are among the most valuable marine high resolution climate archives. One of their unique characteristics is that varves persist well into the Younger Dryas cold period (12.9-11.7 kyr b2k), allowing to reconstruct high frequency climate and environmental variability across the most recent transition from a cold to warm period: the Pleistocene-Holocene boundary.

Here, we present our approach to decode the information stored in this archive via mass spectrometry imaging of molecular proxies. This technique enables µm-scale mapping of molecular proxies, which results in climate and environmental reconstructions with sub-annual resolution. Paired with elemental mapping and high-resolution sediment images, molecular proxy data can further be deconvoluted into season of deposition, thus allowing an assessment of past seasonality.

We analysed a section spanning ~700 years of varved sediments across the Younger Dryas-Holocene transition for a suite of molecular proxies and biomarkers with this approach, and demonstrate that this most recent event of abrupt global warming led to strongly increased sea surface temperature seasonality. We further evaluate how this change affected marine ecology and how it relates to seasonality on land.

With this contribution, we aim at presenting the approach of mass spectrometry imaging to the broader community studying varved deposits and at demonstrating the sensitivity of high frequency tropical climate and environmental variability across critical climate transitions.

A comparison of δ18O records derived from planktonic foraminifera and pteropoda from off Oman margin over the last glacial-interglacial cycle

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The present study presents paleoclimatic results generated on a sediment core retrieved from the upper shelf of the Oman margin. It represents the glacial-interglacial period from 29,000 to 3,000 years BP. Stable oxygen and carbon isotopes have been generated using planktonic foraminifera (*Globigerinoides. ruber*) and Pteropoda (*Limacina inflata*). It is the first study from the Arabian Sea based on the comparison between responses of calcitic foraminifera and aragonitic pteropoda to the changing fresh water influx and temperature variations in the water column. The $\delta^{18}O_{L.\ inflata}$ shows more prominent climatic boundaries, and more events than the $\delta^{18}O_{G.\ ruber}$. The $\delta^{18}O_{L.\ inflata}$ also, throughout the core responds prior to $\delta^{18}O_{G.\ ruber.}$ The records suggest that the aragonitic pteropods are more temperature sensitive than the calcitic foraminifera, making them more efficient proxies for the paleoclimatic reconstruction.

Biomarker and chironomid inferred temperatures from varved records across Europe during the Holocene: trends, precision and seasonal indications

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Annually laminated (varved) lacustrine sediments are invaluable to palaeoclimatologists as they not only provide a tool to establish highly-resolved chronologies, but they also facilitate palaeoclimate reconstruction in unprecedented detail. In turn, this enables an assessment of the relationships between different proxies and the disentanglement of proxy-climate variability (e.g. seasonal vs annual components). Whilst annually laminated sequences are somewhat restricted spatially; long and continuous varved records do exist across continental Europe and analysing a network of these sites allows for the deciphering of climate heterogeneity. Our work aims to develop palaeotemperature reconstructions from varved lake records to assess not only heterogeneity in palaeoclimate, but also to highlight and provide comparisons between different proxy-based palaeoclimate reconstructions. Here we present preliminary results from chironomid-inferred mean July temperature reconstructions and lipid biomarker-based palaeotemperature reconstructions from a select number of varved records across continental Europe. We focus our analysis on two separate time-periods a) over the last 200-years and b) between 5.0 and 6.4 ka BP, covering peak Holocene summer warmth in north-west Europe. This approach enables a calibration with modern instrumental records but also enables a test of proxy-climate variability under different climate background scenarios, including those warmer than the present day. The data from the sites has a temporal resolution of between 4 to 17-years per sample and we will compare the chironomid- and biomarker-inferred temperature reconstructions in terms of trends across the two proxies, precision of the reconstructed data series and variability between seasonal responses, including spatial variance. Ultimately, this work will produce decadal to sub-decadal climate reconstructions and will be used to reconstruct the different modes of climate variability that operated during the Holocene. This work is a contribution to the Decadal project.

Paleoenvironmental evolution of Laguna Seca lake (Sierra Nevada, southern Iberia) since the Late Glacial

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Laguna Seca lake at 2259 masl has provided the longest alpine sedimentary record in southern Iberia, registering the last ~18 kyr in a ~14-meter-long sediment core. The oldest part of the sedimentary record represents a phase of subaerial debris flows and a small glacier/nivation hollow. The sediment characteristics abruptly changed at ~15.7 cal kyr BP, when a lake environment was established. A multi-proxy approach (magnetic susceptibility, organic geochemical analyses in bulk sediment, XRF core scanner data, and algae identification) has allowed the characterization of three different environmental phases in this lake. Deep lake conditions are identified from ~15.7 to ~10.6 cal kyr BP, agreeing with overall increasing precipitation in southern Iberia coinciding with augmenting summer insolation. This part of the record is characterized by grey lutites with high total organic carbon (TOC) content, high algae productivity, high vascular plant inputs (high C/N ratio) from the catchment and low Fe/S ratio, suggesting low oxygen conditions in the water-sediment interphase. Between ~10.6 and 8.2-8.0 cal kyr BP higher TOC and low Fe/S ratio are also recorded as well as higher algae content and low C/N ratio suggesting high aquatic production and more algae contribution to the local organic matter pool. This period registered the highest lake levels agreeing with summer insolation maximum and highest precipitation in southern Iberia. An abrupt lowering of the lake level is recorded after 8.0 cal kyr BP in the area. This is deduced by the decrease in TOC and algae in the sediments and more siliciclastic contribution from the catchment basin, evidenced by a high increase in siliciclastic elements (Si, Al, K, Ti, among others), with increased oxic conditions in the water-sediment interphase pointed out by the high increase in Fe/S ratio. Additionally, a potential increase in north African aeolian inputs (rich in Fe cations and Fe compounds) can be interpreted for the Middle and Late Holocene, evidenced by high Fe/Al values. This environmental change agrees with an aridification trend previously observed in the southern Iberian Peninsula.

European tree migrations during the Holocene

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Recent climate change has caused changes in phenological responses and some shifts in species ranges, but it is unclear whether trees will be able to migrate fast enough to keep up with projected future changes in climate. Observed changes in the distribution of trees during the Holocene (11.7 ka – present) provide a way of documenting tree migration rates in response to climate change. However, there is an ongoing debate about whether tree migration patterns during the Holocene reflect climate change directly or were a lagged response to these climate changes. We use fossil pollen samples from 1305 sites across Europe to reconstruct past changes in summer temperatures (MTWA), winter temperatures (MTCO), growing degree days above a baseline of 0° C (GDD_0) and an index of plant-available moisture (RTMI) during the Holocene. We then used these reconstructions with a generalised additive model (GAM) of the climate space of *Picea abies* and *Fagus sylvatica* to predict the changing distribution of these two trees in response to climate changes through the Holocene and compare this with observations of their actual distribution. We show that climate adequately explains the northward and westward expansion of *Picea abies* during the past 12,000 years. However, the climate-based predictions show a faster and larger northward expansion of *Fagus sylvatica* than was actually observed, providing evidence that other factors, including migration lag from glacial refugia, were an important control on the spread of this species. The application of this modelling approach to the migration of other European trees during the Holocene will provide insights into their adaptive capacity in the face of climate change.

Sensitivity of the French Mediterranean mountains to climate change and human activities since the end of the last deglaciation

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Managing water resources and environmental risks in high mountain environments is of major importance for societies around the Mediterranean. Current climate changes show faster warming at high altitudes and in the Mediterranean region than the global average (+2°C compared to pre-industrial levels). The Hydro-ALPS project aims at providing new continuous paleoclimate records in order to improve regional climate models by integrating processes occurring at millennial time scale. The close interactions between human activities, climate change and the occurrence of extreme events, will also be explored using a multiproxy approach (sedimentology, geochemistry, palynology). Emphasis will be placed on the use of diatoms, microscopic siliceous organisms abundant in alpine lakes.

This contribution presents the first results from the coring of Lake Petit in September 2022 (Valdeblore, France) located at 2200 m a.s.l. Previous studies covering the last 4800 years, have revealed the high diatom content of the sediments and high sensitivity of the lake ecosystem to past climate variability. This new coring has allowed us to retrieve a 7 meters-long sedimentary sequence that extents environmental reconstructions up to the early stages of the lake infilling. The majority of the record is composed of olive to brown diffuse laminae of diatomaceous sediments and the bottom 30 cm of an alternation of millimeter-thick light blue clay and black laminae. In comparisons to previous studies in this region (e.g. Lake Allos, Lake Vens, Lake Long Inférieur), this sedimentological succession suggests that the sequence dates back to the end of last glaciation (likely from the Younger Dryas).

The chronological framework of the different lithological units will be determined by ^{14}C analyses on macroremains of terrestrial origin. First inferences on the lake and watershed evolution will be based on CHNS analysis and biogenic silica content of bulk sediments, X-Ray Fluorescence core scanning and diatom assemblages. Additionally, oxygen isotopic composition ($^{18}O/^{16}O$ or $\delta^{18}O$) in modern waters will be analyzed to better understand the current hydrological functioning of Lake Petit. The new $\delta^{18}O_{diatom}$ record will be used to evaluate lake water temperature, lake water balance (P/E) and precipitation sources.

Holocene seasonal temperature evolution and spatial variability over the Northern Hemisphere landmass

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The origin of the temperature divergence between Holocene proxy reconstructions and model simulations remains controversial, but it possibly results from potential biases in the seasonality of reconstructions or in the climate sensitivity of models. Here we present an extensive dataset of Holocene seasonal temperatures reconstructed using 1,310 pollen records covering the Northern Hemisphere landmass. Our results indicate that both summer and winter temperatures warmed from the early to mid-Holocene (~11–7 ka BP) and then cooled thereafter, but with significant spatial variability. Strong early Holocene warming trend occurred mainly in Europe, eastern North America and northern Asia, which can be generally captured by model simulations and is likely associated with the retreat of continental ice sheets. The subsequent cooling trend is pervasively recorded except for northern Asia and southeastern North America regions, which may reflect the cross-seasonal impact of the decreasing summer insolation through climatic feedbacks, but the cooling in winter season is not well reproduced by climate models. Our results challenge the proposal that seasonal biases in proxies are the main origin of model–data discrepancies and highlight the critical impact of insolation and associated feedbacks on temperature changes, which warrant closer attention in future climate modelling.

Pattern of precipitation changes in eastern China during the Holocene

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A certain number of case studies and model simulations reveale that over the Holocene there represent several dry-wet spatial patterns in eastern China. However, the accurate spatiotemporal changes of the Holocene precipitation over eastern China remains unclear, which hinders our understanding of the mechanism of East Asia monsoon evolution and the prediction of precipitation changes in the future. Here, we present a synthesis of pollen-based precipitation reconstructions over the past 12,000 years based on thirty high-resolution pollen records selected from the eastern monsoon region of China. In general, the overall trend of the precipitation changes in the eastern China increases at first then decreases afterwards, but with different precipitation phase. Therefore, four regions, i.e., South China, the middle-lower Yangtze River, North China and Northeast China, are divided for regional comparisons. The synthesized precipitation series shows that i) during the early Holocene (12-9 ka), the precipitation in eastern China increases consistently, but with higher values in South China and more significant fluctuations in the middle-lower Yangtze River; ii) during early-middle Holocene (9-6.5 ka): the spatial pattern of precipitation presents as “north wetting and south drying”, in which the south region refers to the South China indicated by the low precipitation values; iii) during the middle Holocene (6.5-3 ka): a reversed pattern of “north drying and south wetting” is formed in eastern China, inferred from rapid decrease of precipitation in Northeast China and gradual decrease in North China and the middle-lower Yangtze River, but increase in South China; iv) during the late Holocene (after 3 ka) , the precipitation in eastern China increases generally decreases. This spatiotemporal precipitation variability is better visualized by northward and southward shift of the 400 mm precipitation contour reconstructed by this study. Comparison of the rain belt changing with potentially climatic drivers suggests that solar radiation and ITCZ south-north migration will drive the change of monsoon intensity and the migration of rain belt in eastern China. This study provides quantitative evidence of precipitation variation in the monsoon region of eastern China.

Fire history since the LGM period in the Qinling Mountains, east-central China

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Fire frequency and intensity are increasing with the global warming in recent years. Fire activity can change forest cover from a “carbon sink” to a “carbon source”, which has an important impact on the global carbon cycle and climate changes. Therefore, the study of fire history and regimes at long time scales can provide a theoretical basis for future fire management and biodiversity conservation in forest areas. In this study, the alpine lake sediments (Daye Lake) in the Qinling Mountain Range were used to explore the interaction between fire, vegetation and climate changes, as well as human activities since the LGM period in east-central China based on charcoal and black carbon. The results show that the increase of fire activity during the last glacial period was controlled by arid conditions under the weak East Asia summer monsoon in Qinling region. Human activities played an important role on fires activities since the middle Holocene and human-induced fires became more common than the natural fires in the late Holocene because clearance of wasteland for agriculture and warfare increased fire frequency. Fire peaks were determined by biomass and vegetation composition affected fire intensity. The biofuel was dominated by woody plants in the last glacial period inducing high intensity fires and herbs have more contributions over the mid-late Holocene due to high fire frequency. With future increasing temperature, the increased vegetation cover and extreme climate events may increase the fire risk in the Qinling Mountain Range. Therefore, it is important to strengthen scientific management and monitoring of the forest ecosystem for regional ecosystem conservation.

Late Pleistocene to Holocene Black Sea transition from a lake to a marine basin: geochemical and biotical approaches

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During the Last Glacial Maximum (LGM), the Black Sea evolved as a giant fresh to brackish-water lake. In the Early Holocene, an outstanding event took place in the Black Sea: the end of the lacustrine stage of this basin caused by the reconnection with the Mediterranean as a consequence of the last deglaciation, which led to the onset of a marine anoxic regime in the basin, similar to the present day one. This paper presents the investigations carried out on 13 gravity cores, located in the W Black Sea, at water depths between 140 and 1,315 m. All three Upper Pleistocene-Holocene units of the Black Sea, namely the Lacustrine Lutite (Unit 3) – the oldest, the Sapropel Mud (Unit 2) and the Coccolith Mud (Unit 1) – the youngest, have been intercepted. Unit 3 contains a distinct red-brownish depositional interval, which occurs only in the W Black Sea. The recorded absolute ages indicates that the oldest core interval in Unit 3 is about 21,000 years BP, being situated in the cooler interval of LGM. Towards the lower part of Unit 2 an absolute age of 7,420 years BP was observed, while towards its top an age of 4,232 is recorded. The lacustrine sediments of Unit 3 enclose mainly Ponto-Caspian ostracods, except for the top part of the same unit, within the red-brownish interval, where the Mediterranean taxa occurs. Calcareous nannoplankton taxa are missing in the Black Sea pre-connection stage, but few specimens of *Emiliania huxleyi* are present at the top of Unit 3, just below the deposition of Unit 2 (Sapropel Mud). This finding indicates that the salinity was at least 10-11 ‰ (lowest limit of surviving for *Emiliania huxleyi*) prior the Sapropel Mud deposition. The above-mentioned biotic modifications are accompanied by significant geochemical changes, i.e., isotope values, including the shift of $d^{18}O$ from the Late Pleistocene to Holocene times and important fluctuation of $CaCO_3$, TOC (Total Organic Carbon) and OM (Organic Matter).

The Holocene of Sweden - what do we know and what is left to answer?

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Research on Holocene climate variability has a long history in Sweden going back to the Late 1800s and many ideas and concepts about changes in temperature and precipitation during the Holocene originated in Fennoscandia. The Holocene climate evolution in Sweden follows a pattern in common for many northern latitude records, following the summer insolation trend of the NH. A rapid warming at the Pleistocene-Holocene boundary at c. 11,650 cal a BP was followed by the Holocene thermal maximum between c. 8000-5000 cal a BP. A transition to colder and wetter conditions starts c. 4000 cal a BP, or in some records already around 6000 cal a BP, and lasts until the late 1800s CE. There is evidence from proxy records for climatic anomalies such as the 8.2 and 4.2 ka BP events and the Little Ice Age (LIA) but only scarce evidence for some other events, such as the 10.3 ka BP event. Despite the multitude of investigations, several research questions remain unanswered and remain to be addressed. Some of these questions will be addressed in this presentation.

Stable isotope, biogenic calcite crystal structure and biotic proxy based low stands of Lake Balaton at 8.2 and 5.3 kyr BP, the largest shallow lake of Central Europe

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Increasingly frequent periods of drought fundamentally change the sediment-water balance in continental waters (rivers, lakes), and consequently the water quality. This is especially true for shallow, large lakes, like Lake Balaton. In this lake, biogenic calcite precipitation contributes over 80% of the total sediment accumulation. To understand how past lake level changes correlated with trophic level, lakeshore occupation and land use changes 1 full Holocene and 1 short (last 500 years) sediment core from the central part of the lake was studied for TOC, TN, micro-XRF, TEM, XRD, ICP and chlorophyll together with chironomid, diatoms and pollen analyses. For dating, $^{210}Pb/^{137}Cs$ and AMS ^{14}C measurements were used on pollen extracts and plant macrofossil samples. Regional plant cover estimates were made by the REVEALS model.

Biogenic carbonate precipitation in Lake Balaton produces calcite and Mg-calcite. Their relative proportions strongly depend on the Mg saturation of the water. Modern observations prove that increased Mg-content in the biogenic calcite correlates with increased evaporation of the water. Using this relationship for the past and corroborating it with $d^{18}O$ and $d^{13}O$ measurements and TEM derived crystal structure, we found two periods of Mg-calcite increase in the Holocene, at 8200-7900 and 5300-4600 yrs cal BP that likely indicate drier climatic conditions connectable to well-known rapid climate change events. Pollen data showed that the watershed was characterised by increased forest fires during these intervals. Our data furthermore show that the lake was characterized by mesotrophic deeper water with strong biogenic carbonate precipitation from 4200 cal BP until AD 1700, which was followed by a sudden increase in organic productivity between AD 1700-1750, simultaneously with a decrease in water-depth. Sediment accumulation (0.15-0.43 mm yr^{-1}) and sedimentary P (0.32-0.5 mg g^{-1}) content was fairly even in the Holocene, and did only accelerate in the second dry period in the central Szemes Sub-basin suggesting that high stand have not been connected with increased P-recycling. The second low lake stand phase coincides with the Baden occupation of the lakeshore, where we see changes in the d18O records overall pointing to a cold period at 5300 cal BP. Supported by NKFIH129167, RRF-2.3.1-21.

Abrupt early-Holocene climate and vegetation dynamics in a high-resolution lake core sequence from northern Finland

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Holocene proxy data indicate repeated abrupt, sub-millennial disruptions in northern hemisphere climate in the early part of the current interglacial (12–8 ka), commonly linked to the climatic and oceanic impacts of freshwater routing and outburst floods related to the residual ice sheets in North America and Europe. However, the precise climate signals of these abrupt events remain poorly resolved, including the amplitude and seasonality of associated temperature and moisture changes, as well as spatial expression and possible inter-regional correlations. This is due to the paucity of high-resolution proxy datasets, as well as seasonal biases in the available proxies, hampering a consistent hemispheric detection and characterization of the events.

In this study, we describe a core sequence from Kuutsjärvi, northern Finland (67.75°N 29.61°E), analysed for climate and vegetation proxies including pollen, plant macrofossils, sedimentary ancient DNA (*sed*aDNA), as well as conifer stomata and non-pollen palynomorphs (NPP's) analysed from pollen slides. A quantitative mean July air temperature reconstruction is prepared from the pollen data using a calibration model ensemble including both classical and machine-learning approaches. With robust chronology (23 radiocarbon dates) and high resolution (mean pollen sample interval 47 years and mean *sed*aDNA interval of 157 years over 10.7–4 ka), the Kuutsjärvi proxy data reveal a sequence of abrupt climate and vegetation shifts over the early Holocene.

Our data show a transient presence of both *Picea* (spruce; pollen, stomata, and potential *sed*aDNA evidence) and *Larix* (larch; pollen evidence) around Kuutsjärvi over ca. 9–7 ka. This is the first confirmed find of *Larix* in Finland during the Holocene. Two deforestation spikes occur at 10.4 and 10.1 ka, possibly correlative with a two-pronged signal of the 10.3k climate event in Greenland ice-core δ^{18}O data and in speleothem proxies for the East Asian summer monsoon. A strong tree minimum at 8.4–8.0 ka is correlated with the 8.2k climate event based on timing and a temporal progress (gradual build-up, sharp recovery) matching Greenland δ^{18}O records. Shallow-water indicators in the NPP record suggest a fall in moisture balance in northern Fennoscandia during the 8.2k event.

Holocene Climate and Environmental Change in Southeast Iceland

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Understanding natural climate variability is an important topic of discussion, with particular focus on the Holocene. Iceland's location provides an excellent opportunity for understanding Holocene North Atlantic climate variability and ocean circulation. Changes in the boundaries of major atmospheric and oceanic currents in the North Atlantic play an important role in both regional and global climate change and are known to impact changes in terrestrial climate in Iceland.

Palaeolimnological studies in Iceland have demonstrated their potential for reconstructing Holocene terrestrial climate and producing both quantitative and qualitative palaeoclimatic reconstructions using chironomid (non-biting midges) based temperature reconstructions. However, these studies are focused in the north and northwest, with little known of southeast Icelandic climate prior to the Little Ice Age (ca. 1250-1900 AD). Southeast Iceland also comprises Europe's Largest ice cap, the Vatnajökull ice cap, which has several outlet glaciers that are sensitive to changes in climate and provides an excellent opportunity to examine glacier chronology and extent in response to changing climate and marine conditions.

This study combines geomorphological and palaeolimnological evidence to reconstruct Holocene climate and palaeoenvironmental change in southeast Iceland. Lake sediment cores have been collected from high altitude lake Káravatn, to provide the first chironomid-based palaeoclimatic reconstruction in southeast Iceland. Quantitative analysis will include ITRAX x-ray fluorescence and x-radiography, particle size analysis, magnetic susceptibility, and organic matter content, alongside radiocarbon dating and potential tephrochronology. These complementary proxies will give insight into the presence of tephra, lake productivity, soil erosion, organic matter content and catchment disturbance. Glacial geomorphological mapping has been carried out at nearby Skálafellsjökull, a southeast outlet glacier of the Vatnajökull ice cap, using a high resolution aerial orthophoto and digital elevation model, collected using an uncrewed aerial vehicle. Samples for cosmogenic He-3 nuclide dating have been collected from glacial erratic boulders from nearby mountain Skálafellshnúta, to constrain ice thickness and extent since the Younger Dryas.

This evidence from southeast Iceland will help to refine Holocene climate history, as well as further understand the relationship between North Atlantic Ocean circulation, terrestrial climate change and glacier response in this key region.

Deducing the timing of oceanic and ecosystem regime shifts south of Iceland across abrupt late Pleistocene climatic transitions: a multi-record, multi-method approach to geochronology

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Independent chronological constraints on paleoceanographic reconstructions from marine sediments are vital when comparing local regime shifts with global atmospheric and oceanic circulation patterns through time and space. To investigate oceanic and marine ecosystem responses to abrupt climate change, we retrieved sediment cores from the Iceland and Irminger Basins (S-SW Iceland), situated along the inflowing Irminger Current and within the known region of polar frontal positions. We apply a multi-method chronological approach to a selection of these cores. At varying resolutions, we estimate that these records date from Marine Isotope Stage (MIS) 3, with one record likely extending back to at least 80 ka BP. We apply a range of geochronological techniques to constrain the timing of sea (sub-) surface temperature regime shifts derived qualitatively (planktonic foraminifera assemblages) and quantitatively (stable isotopes and Mg/Ca palaeothermometry). Dating methods include radiocarbon and paleomagnetic (relative paleointensity, paleosecular variation) dating, as well as tephrochronology, given the proximity to and extent of Iceland´s explosive volcanism. Dating methods independent of climatic variation (such as tephrochronology and relative paleointensity dating used here) are rather powerful as they allow us to establish appropriate local reservoir corrections to marine radiocarbon dates back through time. Secondly, by avoiding tuning our proxy records to e.g., ice core stratigraphy, we can better constrain lead/lag events of local oceanic and ecosystem regime shifts south of Iceland to millennial-scale global changes. Ultimately, this multi-method approach will allow us to establish a much needed reference event stratigraphy for future paleo-studies in this dynamic region.

Late Pleistocene to Holocene depositional environments in the Southern East Siberian Sea

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New data on the geological sequence, composition, and genesis of Quaternary deposits in the most poorly studied area of Russian Arctic – southern East Siberian Sea and southwestern Chukchi Sea - were collected during marine geological expeditions of A.P.Karpinsky Russian Geological Research Institute (VSEGEI) carried out in 2018 and 2020. During these cruises, 3400 km of seismic survey (UHR) and sub-bottom profiling (SBP), 3200 km of side-scan sonar survey and multibeam echo sounder, 191 surface sampling sites (box corer) and 31 long cores (gravity corer) were obtained. Five acoustic units of Quaternary deposits were identified. The upper two (Late Pleistocene and Holocene) were studied in the sampled sediment cores. Processing and interpretation of geophysical data, and the multiproxy study of sediment cores, including layer-by-layer grain-size, geochemical, diatom, palynological, and microfossil analyses as well as radiocarbon dating, were used for reconstructing geological development of the region in accord with palaeoclimatic and palaeogeographic aspects of its environmental evolution in the Late Pleistocene and Holocene. During the Sartan cold epoch (MIS 2) the studied offshore area was exposed. No glacial landforms were found of the seafloor. During the first warming stage and the onset of transgression (18-11 ka BP) the studied area remained exposed. According to lithology, geochemistry, diatom and microfossil analyses, sediments of this age mainly accumulated within shallow freshwater thermokarst lakes and river valleys. Pre-Holocene bottom topography predetermined the east-west direction of the shallow shelf flooding. By 11 ka BP, a large semi-enclosed lagoon was formed to the east of Wrangel Island, in the Chukchi Sea. About 10 ka BP, the area around Wrangel Island was separated from the mainland by straits, and elongated estuaries were formed within palaeovalleys of the Kolyma and the Indigirka rivers. By 8.5 ka BP, the palaeocoastline in the eastern East Siberian Sea was close to the modern one, while New Siberian Islands remained connected with the mainland. Sea level rise in the Holocene was irregular as evidenced by characteristic submerged landforms (longshore bars, underwater terraces, foredeltas, etc.) and stabilized around 5 ka BP. This research was supported by the Russian Science Foundation, project 22-27-00412.

The Climate Complexity of Atmosphere, Water Masses & Ice-Drift Patterns in the Nordic Seas: New Insights from the Holocene

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Temperature-sensitive climate proxies from the north polar latitudes – ice cores, terrestrial and marine archives alike – show a tight connection to northern insolation with highest temperatures noted in the early Holocene. For further in-depth understanding of the post-glacial environmental development within and around the Arctic the Nordic seas are of special interest because it comprises a through road for the oceanic heat from the N. Atlantic via the Norwegian Atlantic Current (NAC) northward on the one hand and the southward flow of polar waters from the Arctic Ocean on the other. The situation leaves the formation of three oceanographic water mass components separated by the Arctic Front (AF) and the Polar Front (PF).

Using O-isotopes, planktic foraminiferal assemblages and ice-rafted detritus (IRD). It is shown that highest surface temperatures occurred between 11 and 9 ka. An intermittent cold phase around 8 ka is associated with IRD and increases of polar species *N. pachyderma.* Afterwards, higher surface temperatures were regained but started to decrease at the AF after 6 ka, concomitant with a persistent occurrence of IRD and a cooling trend which continued until today. Within the warm NAC water mass, by contrast, relatively stable and warm conditions persisted until 2.5 and 1 ka, in both planktic and benthic O-isotopes. Although variability among certain foraminiferal species would indicate some surface changes, the abundance of *N. pachyderma* increased to 70 % during the last 1ka (i.e., during the Little Ice Age). That drastic increase was associated with highly variable O-isotope values throughout the entire water column.

While records until the mid-Holocene (5-6 ka) occurred under circumstances still related to the overall post-glacial environmental reorganization (i.e., deglaciation, global sea-level rise and associated Arctic Ocean sea-ice expansion onto the vast shelf areas), the situation observed since then is interpreted to be mainly driven by atmospheric circulation changes. The atmosphere forced more Atlantic surface water towards the Arctic during the last few millennia, a situation which invigored water mass dynamics and frontal system changes in the Nordic seas.

A Holocene multiproxy record to assess ice-ocean interactions and ecosystem changes in Melville Bay, northwest Greenland

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Amplified warming of the Arctic region is leading to enhanced discharge from the Greenland Ice Sheet and accelerating loss of sea ice. These rapid changes in the Arctic cryosphere affect the ocean circulation, earth's albedo, ocean-atmosphere heat and gas exchange and polar ecosystems. At the base of the marine food web, primary producers such as sea ice microalgae and phytoplankton (including diatoms and dinoflagellates) are important in sustaining higher trophic levels. Marine sediment records are valuable archives holding past environmental information to assess how a changing cryosphere impact the marine ecosystem functioning and structure. We will present results from a recently retrieved Holocene core from Melville Bay, Northwest Greenland (gravity core LK21-IC-St26-GC1; 75°19'10.67"N, 61°54'24.44"W; water depth 912 m). Melville Bay is a climate-sensitive region receiving substantial volumes of meltwater discharge from the Greenlandic Ice Sheet that is subject to strong seasonal sea ice variability. Furthermore, this region benefits from a protection status as a marine wildlife sanctuary. We designed a multi-proxy approach to reconstruct past seasonal sea ice, ocean circulation and marine productivity changes based on biomarkers (Highly-branched isoprenoids or HBIs, including IP_{25} (Ice Proxy with 25 carbon atoms), phytosterols and microfossils (dinoflagellate cysts and foraminifera) as well as bulk descriptors of organic matter composition (e.g., total organic carbon (TOC), nitrogen (TN), sulphur (TS), calcium carbonate (CaCO3) and stable isotopes (13C and 15N)). We explore past responses to climate variability recorded in this Melville Bay sedimentary archive and implications on the ecosystems under a sustained warming trend in the Arctic region.

A promising archive of High Arctic Holocene temperature variability: lake sediments from Peary Land, North Greenland

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Arctic amplification of global warming is resulting in alarming rates of temperature rise in the High Arctic, and rapid changes to landscapes and ecosystems. To constrain the sensitivity of High Arctic sites and make meaningful predictions about future change, we must examine the sensitivity of these regions to past changes using natural archives. We will report on the potential of the varved lake sediments of "Lake SW" in Peary Land (82.1°N, 35.7°W), located 3km northeast of the Storm Iskappe glacier, as a high-resolution temperature archive to expand the regional temperature history beyond the instrumental measurement period. The sediments were collected in August 2021 and a robust chronology was established using a combination of varve counting and radionuclides (^{210}Pb, ^{137}Cs, ^{241}Am and ^{14}C). A suite of scanning techniques was then employed (computed tomography, µX-ray fluorescence scans, hyperspectral imaging) together with alkenone-thermometry (U_K^{37}), C/N- and diatom analyses to reconstruct the lake's productivity (green pigment concentrations and fluxes, *GP*), anoxia (bacterio pheophytin concentrations and fluxes, *BPhe*), and temperature histories over the last millennium.

We observe the highest *BPhe* values between ~1490-1900CE suggesting a phase characterized by prolonged anoxia. Simultaneously, the diatom assemblage along with low alkenone-derived temperatures indicate cold and dark icy conditions characteristic for heavy ice cover. This phase coincides with the LIA, and thus might be caused by regular perennial ice-cover extents that increase thermal stratification of the water column (oxygen depletion). Between ~1900-1990CE an increase in *GP*, and a diversification in the benthic diatoms may be associated with larger moating around the lake, more nutrient input and slightly higher water temperatures. The period after ~1990CE is characterized by the arrival of planktonic diatoms, the warmest observed alkenone-derived temperatures, and a significant decrease in *BPhe* suggesting extended periods of open water. Further statistical comparison of the *GP* and temperature will reveal whether the productivity is limited by temperature, which would allow proxy-to-proxy-calibration to increase temporal resolution of the temperature record.

We present evidence that sediments from "Lake SW" are a promising high-resolution archive of local temperature variability for the late Holocene in an area that is lacking high-resolution terrestrial paleoclimate records.

Holocene Hydroclimate, Catchment Development and Ontogeny as Drivers of Arctic Lake Carbon Cycling

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Lakes are an abundant feature in the Arctic, and act as long-term storage and atmospheric source of carbon (C). The fast warming in the Arctic is coupled with an intensified water cycle due to the sea ice decline enhancing atmosphere-ocean interactions. Climate change can potentially alter lake C cycling through higher temperatures enhancing aquatic productivity, but also through increasing precipitation as rain that may amplify terrestrial C load. Thus, the rate of C accumulation and the sources of organic C to lakes will potentially be altered. However, the link between hydroclimate change and C cycling in Arctic lakes is not fully understood. Lake sediments allow the study of C cycling responses to past climate fluctuations.

Here, we present records from Lake Kuutsjärvi, northeastern Finland, to examine Holocene changes in the quality and quantity of organic C in the sediments (total organic C and nitrogen -N, and $\delta^{13}C$, $\delta^{15}N$) and their possible coupling with regional hydroclimate change ($\delta^{18}O$ from fossil chironomid head capsules). We use modern-day materials to calibrate both geochemical approaches. Modern lake OC sources differentiate discernible geochemical groups for terrestrial vegetation, aquatic vegetation (~benthic mosses), as well as phytoplankton. Lake water and precipitation water isotopes collected over full annual cycle show that the lake represents isotopic composition of local precipitation, even in summertime. The results show that climate is the main driver of the C accumulation rates and the proportional contributions of aquatic and terrestrial sources through time, data also demonstrates the important role of changes in lake ontogeny and catchment land cover. Organic C accumulation rate (OCAR) was low in the early Holocene, then rising with higher terrestrial contribution during the Holocene Thermal Maximum (HTM) and subsequently decreased significantly with increasing contribution from aquatic production. The warm HTM climate likely changed the hydrologic mode towards partially closed, and together with the denser vegetation increased the terrestrial C load. In the late Holocene, apparent OCAR slowdown was caused by sediment infilling, while aquatic sources predominated probably because of the upsurged moisture that opened the system and allow terrestrial material to flow out of the lake.

Nuanced responses of seasonal sea ice to a warmer Arctic climate during the Holocene Thermal Maximum

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While climate model simulations provide valuable insight into potential future Arctic sea-ice scenarios, marine geological archives offer key information on how sea ice responded to substantial climatic warming in the past, particularly during periods characterized by warmer-than-present conditions. The HTM (Holocene Thermal Maximum), ~10.0-6.0 cal ka BP, was the last major period of warm climate expressed in warmer air and ocean temperatures across the globe. Although a result of orbitally-forced summer insolation, the HTM constitutes a valuable parallel to the greenhouse-gas-driven setting of a current (and near-future) warmer world. At higher latitudes in the Northern hemisphere, the HTM has been proposed as an interval of reduced sea ice and increased Atlantic water inflow, similar to a projected future warmer Arctic Ocean. Two sediment archives elucidate the early Holocene HTM evolution of high Arctic seasonal sea ice in the northern Barents Sea (>80°N), a key area for Atlantic-Arctic Ocean water interaction in a hotspot of current climate warming. HBI (highly-branched) biomarkers (IP_{25}, $IPSO_{25}$, HBI III, HBI IV) unequivocally demonstrate the persistence of spring seasonal sea-ice as high as 55% between 11.7 and 9.1 cal ka BP. Concomitant high $\delta^{18}O$ in benthic foraminifera and elevated phytoplankton biomarker (HBI III, HBI IV) concentrations indicate the influence of warm Atlantic-derived bottom water and peak bioproductivity, respectively. Our results highlight the nuanced and complex cryospheric response to climate warming, showing High Arctic sea ice persisting in a setting of warmer-than-present spring and summer conditions under a concomitant increased inflow of subsurface Atlantic Water. This raises important questions about the fate of Arctic sea ice, oceanography, and ecosystems (including commercially important fisheries) in an increasingly warmer climate driven by anthropogenic factors.

Methane cycling in lakes in Alaska in response to warmer and wetter conditions during the Holocene

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Global temperatures are increasing at an unprecedented rate, with northern high-latitude regions warming almost twice as fast as the global average. High-latitude landscapes hold a large proportion of the world's freshwater lakes and ponds, which are highly vulnerable to climate change and a natural source of methane, a fundamental greenhouse gas. As temperatures rise, methane emissions from these lakes are also expected to increase; however, the magnitude and timing of this increase remains uncertain.

Proxy-based estimates of lake-methane production during warmer periods, such as the early Holocene (8,000 - 11,000 cal BP) can help validate model simulations of how much methane can be produced and released in lake systems under warmer climates. These proxies include the stable-carbon isotope values ($\delta^{13}C$) of aquatic invertebrate remains and bacterial hopanoids. The $\delta^{13}C$ values measured on sedimentary remains of these proxies are lower when methane-derived carbon is an important part of the lake carbon cycle. We provide proxy-based estimates of methane production from lakes in Alaska that suggest that during the Holocene Thermal Maximum, methane availability could have been 2-5 times higher than at present.

Tracking circulation change in the western North Atlantic during the Little Ice Age using a multi-proxy approach

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The Little Ice Age (LIA), a period from approximately 1350 A.C. to 1850 A.C., is characterised by an abnormal cooling in the Northern Hemisphere. The role of ocean circulation for the onset of the LIA is still equivocal. Notably, potential changes in the western North Atlantic circulation were highlighted during this period and the changes were found to be linked to a relatively weak Labrador current. Since these studies were based solely on oxygen isotopes, it is difficult to ascertain the cause of the observed change in oxygen isotopic signals to either a change in circulation and water masses influencing the coring location for this study, or to a change in water temperature, or even a combination of both. Therefore, to better understand the ocean circulation dynamic over the LIA in the western North Atlantic, the previously established oxygen isotope result will be constrained from the Mg/Ca ratio data in this study.

Two cores collected in the Laurentian Channel were selected for this study: 1) CR02-23 (48º42.008'N, 68º38.894'W), will be used to establish a Mg/Ca calibration curve against instrumental temperature over the last 60 years; 2) The section covering LIA will be analysed in high-resolution in MD99-2220 (48º38.32'N, 68º37.93'W). The two cores are selected because of the high sedimentation rate in the Laurentian Channel and the already-available oxygen isotopic data. The benthic foraminifera species, *Globobulimina auriculata*., was selected for the Mg/Ca ratio paleo-temperature reconstruction because it has been well-calibrated in other regions and has a high temperature sensitivity.

Using these data, new knowledge about the potential role of ocean circulation and its linkages with cooler condition during the LIA will be produced.

Calibration of subfossil chironomids as paleoclimatic indicators in eastern Canada and application for forest ecosystem dynamic studies

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The concept of reference state is increasingly used to guide environmental policies and management. This is notably the case for Quebec forests, where the pre-industrial natural state serves as a reference for the ecosystem-based management of the modern forest. Palaeoecological records can help define a reference state by providing ranges of natural variability in relation with climatic fluctuations. This kind of approach requires appropriate and independent reconstructions of vegetation, perturbation regime and climate at local and regional scales. However, in temperate and boreal regions, paleoclimatic and vegetation data are often derived from pollen assemblages, leading to circular reasoning. Consequently, other paleoclimatic proxies independent of vegetation should be used. Our long-term goal is to develop the use of subfossil chironomids from lake sediment as summer temperature indicators in eastern Canada, with the final purpose of carrying out multiproxy studies on the dynamics of forest ecosystems. We assessed the environmental control of the modern distribution of chironomid taxa with assemblage data from surface sediment samples distributed along a climatic gradient ranging from the Canadian Arctic to the temperate zone of New England. Canonical analysis identified summer air temperature as the main factor influencing taxonomic composition of assemblages. Thus, as already indicated by previous work in Europe and North America, we confirmed the potential of chironomids as paleoclimatic indicators and a well performing temperature inference model has been developed. This new transfer function was then applied to a 9000-year chironomid record from Lake Charrier, located at the temperate-boreal transition zone of Quebec. This allowed the reconstruction of the major postglacial climatic changes, like the initial warming after the retreat of the Laurentian ice sheet, the Holocene thermal maximum and the Neoglacial cooling. The joint analysis of the summer temperature reconstruction with charcoal and pollen records also provides new insights into the climatic control of forest ecosystem dynamics in the region during the Holocene.

Chironomid-based palaeotemperature and precipitation oxygen isotope estimates for the North Atlantic region (Azores archipelago)

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The location of the Azores Archipelago in the North Atlantic makes this group of islands an excellent setting to investigate past long-term temperature and precipitation changes in the middle of the North Atlantic region. Here, we present a chironomid-based temperature reconstruction and oxygen isotope composition from chironomid head capsules for the last 1500 years, using Prata Lake sediment record (São Miguel, Azores). The reconstructed mean July air temperatures range between 15.0 and 9.1ºC. The highest temperature values (13.5±1.5ºC) were recorded during the Medieval Climate Anomaly (MCA), transitioning to the lowest temperature values (ranging from 10.5 to 12.7°C) during the Little Ice Age (LIA). Also, changes in lake water oxygen isotope composition from chironomid head capsules were recorded with more positive ∂^{18}O values (18.2±0.2‰), during the MCA and more negative values (vary between 14.8‰ and 17.6‰) during the LIA, indicating a positive shift in the precipitation-evaporation balance and/or heavier precipitation in the winter relative to summer. The chironomid inferred changes in temperature and precipitation track north Atlantic temperature and isotope records indicating that the previously reconstructed high latitude MCA warming and LIA cooling extent to the mid-latitudes of the central Atlantic region. In comparison with past climate model simulations of the region, an overall humid with warmer-than-usual conditions dominated the end of the MCA, and colder temperatures between 1400 and 1500 CE. Changes in the North Atlantic Oscillation (NAO) and Eastern Atlantic (EA) pattern during the last millennium suggest they would be controlling regional winter precipitation and summer temperatures, respectively.

Sedimentary biomarkers and leaf wax hydrogen isotopes reveal complex Holocene climatic and environmental dynamics in the Sumava Mountains, Central Europe

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Lipid biomarkers preserved in lake sediments are increasingly being employed to reveal various facets of past climate and environmental dynamics. For example, hydrogen isotopic ratios (δ^2H) from plant cuticular waxes were used to infer past atmospheric circulation changes or variability in climate modes, while GDGT compounds from bacterial membrane as proxies for palaeotemperature. However, not all processes controlling lipid biomarker and their isotopic variability, that operate at the local scale, are well understood. This, added to the scarcity of Holocene palaeoclimatic records in Central Europe, limits our understanding of continental hydrology and its links to finer-scale palaeoclimatic variability and past vegetation and disturbance dynamics. Here we determine δ^2H from sedimentary leaf waxes to reconstruct Holocene moisture patterns and branched (brGDGT)/ isoprenoid GDGTs (isoGDGT) from sediment organic matter to derive temperature variability, based on a lacustrine archive located in the high coniferous forest belt of Šumava Mountains, Czech Republic. We then employ pollen, charcoal, sediment geochemistry and locally-downscaled climate models to explore local factors (e.g., vegetation structure and type, canopy density, soil characteristics, natural and anthropogenic disturbances) potentially affecting the biomarker signal and reconstructed values.

Results show strongly depleted δ^2H values around 11.5, 9.5, 7.5-7 and 3-2 ka BP and strongly enriched values around 8.2 ka BP. A decoupling between δ^2H of the long-chain n-alkanes originating from higher terrestrial plants, as opposed to medium-chain n-alkanes related to aquatic plants occurred around 6 ka BP and likely reflects the isotopic composition changes due to increasing canopy density of primary forests, soil paludification and absence of disturbances (fire, erosion). The major hydrological patterns over the late Holocene follow the NAO index variability. Reconstructed temperatures based on brGDGT and isoGDGT show a similarly ascending trend until 6 ka BP and diverge thereafter. We interpret the diverging brGDGT values as locally influenced by soil pH, due to the progression of podsolization and paludification processes affecting the catchment soils. Conversely, isoGDGT largely follow winter insolation trends and appear to reflect winter water temperature.

Our data highlight the utility of assessing sedimentary biomarkers within a palaeoecological multiproxy dataframe to disentangle the complex biomarker signals in lacustrine archives.

What do dinoflagellate cyst sedimentary records in the Santa Barbara Basin tell us about the changing ocean?

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Understanding abrupt environmental changes, including those caused by the rapidly warming oceans is a challenging task and requires a compilation of long-term environmental or paleoenvironmental data. Such data are hard to obtain and often even harder to interpret because of unevenness in sampling coverage or potential issues with assembling and interpreting data at different timescales. Dinoflagellate cysts are sensitive and reliable paleoenvironmental indicators, and their use has increased over the last decades, especially for high-resolution applications in the Pacific Ocean. Dinoflagellates are one of the most diverse and abundant groups of microalgae in coastal environments and are major primary producers. During their life cycle, many dinoflagellates produce highly resistant organic-walled resting cysts that accumulate in sediments, and their records contain information about upper water masses at the time of deposition.

In this presentation, we summarize what we have learned from high-resolution dinoflagellate cyst sedimentary records that span from seasonal to annual, annual to decadal, decadal to centennial, and centennial to millennial scales in the Santa Barbara Basin (SBB), southern California. The SBB is a deep semi-enclosed basin located on the NE Pacific margin and is characterized by high primary productivity and restricted deep-water circulation resulting in exceptionally preserved sedimentary records under anoxic conditions. The basin has been extensively studied over decades and can now be considered one of the best-researched sites on dinoflagellate cysts in the world. Cyst census data from the contemporary sedimentary trap record, last century sediments, as well as from the Holocene and the Last Interglacial cores allow us to observe changes in the ecosystem responding to the warming ocean. We attempt to reconcile these inferences and provide a unifying interpretation of our observations.

Response of palynological and chemical proxies to climate variability in the southern Gulf of California from ~4,487 to ~260 years BP.

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Synchronous response from geochemical and palynological data from laminated sediments in La Paz Basin, allow recognition of centennial variations on rainfall and marine productivity from ~4487 to ~260 years BP. Concentrations of the paleoclimate proxies Ti and Fe (terrigenous input) and Mo (anoxia) were obtained by X-ray fluorescence analyses and total organic carbon concentrations (TOC, primary productivity) with a CO2 coulometer. Concentrations of marine (dinoflagellates and copepods) and continental palynomorphs (pollen and spores) indicate changes in marine primary productivity (MPP) and rainfall (RF). Our chemical results have significant statistical correlations and graphic similarity with palynological data obtained from some of the same samples. Concentrations of TOC show an increasing trend through time, and correlate with heterotrophic dinoflagellates and copepods, indicating the predominance of MPP. Values of these proxies separate four intervals: from 4375 to 3050 BP the values are low, reaching medium values from 3050 to 1500 BP, while from 1500 to 900 BP the MPP is low, and from 900-290 BP, reach their highest values. Concentrations of Ti and Fe are statistically and graphically correlated with spores and autotrophic dinoflagellates, indicating their reliability, as proxies for RF. Values of these parameters are relatively stable, and define four intervals. From 4375 to 3700 BP, they represent low RF; then, from 3700 to 3000 BP, RF increased to medium values, and from 3000 to 600 BP, RF increased to high values, with a short dry period from 1250-1200 BP, after which RF reached its highest values (1050 to 600 BP). Finally, from 600 to 290 BP, RF reached mainly medium values. The proxies used in this work allow identification of regional conditions as an extreme drought period (1280-1070 BP) reported in southwestern North America, or global events like the Medieval Warm Period (1078-706 BP) and the Little Ice Age (706-260 BP).

Do past forest fires influence Daphnia abundances in small headwater lakes of British Columbia, Canada?

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Small subalpine lakes in thin soil, crystalline rock catchments are sensitive to catchment scale nutrient releases after high severity forest fires. High-resolution sediment-charcoal records provide evidence of past fires and concentrations of *Daphnia* resting stage egg cases (eggless ephippia) preserve a proxy signal of past abundances, which represent part of the secondary trophic level within the lake. The Holocene sediment record of a small (<100 m diameter, 0.35 ha area), shallow (2.4 m maximum depth), fishless, headwater lake (2074 m asl) in south-east British Columbia, Canada, provided a continuous record (median 14 years per sample) of both charcoal and sclerotized ephippia, analysed to explore temporal relationships and test links between fires and *Daphnia* production. Subsamples of 1 cm^3 were wet sieved (150 micron mesh) to retain charcoal and larger *Daphnia* ephippia. The accumulation rates of charcoal and *Daphnia* ephippia were positively correlated (r=0.42, n=663 samples). Peak-to-peak analyses showed significant synchrony (99% CI) of ephippia abundance peaks at time windows of 20-70 years after charcoal peaks that supported an interpretation of multidecadal-scale interactions between fire, forest recovery and the aquatic ecosystem. Additionally, the high concentrations of *Daphnia* ephippia offered an opportunity to quantify variations in ephippium dorsal length and to index ephippia opacity, both variables can be considered as proxy indicators of adult female *Daphnia* body size and degree of melanin pigmentation of ephippia. These physiological variables relate to visual predation pressure from trade-offs between camouflage and UV protection of eggs and were measured at a lower resolution downcore (n=35). There was little variation in ephippia dorsal length throughout the Holocene (mean=0.812 ± 0.072 mm, n=1246 individuals measured) and ephippia opacity decreased slightly over the Holocene with a higher proportion of more abundant darker ephippia during the early Holocene. The relationship between fires, forest succession and nutrient release into lakes occurs at scales from decades to a century post fire. These time scales coincide with the forest succession that follows severe fires and suggest long-term links between forest development and the aquatic trophic cascade.

Reconstructing past environmental change over the Holocene through marine and terrestrial proxies at Lyttelton Harbour, Banks Peninsula, New Zealand

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Low elevation terrestrial and marginal marine settings will be sensitive to future changes in global sea level, temperature, natural hazards and environmental variability. It is of key importance to understand past environmental changes in order to provide baseline information on the pre-anthropogenically modified state of environmental systems and understand natural variability in these systems. Here we present a reconstruction of past environmental conditions over the Holocene at the marine-terrestrial interface at Lyttelton Harbour, Banks Peninsula, New Zealand. Banks Peninsula is a culturally, geologically and historically significant location in New Zealand representing among other things the southernmost limit for indigenous (Maori) agriculture, specifically kumara (sweet potato) cultivation in New Zealand. The peninsula also contains many micro-environments and significant terrestrial and marine resources for human populations. It is both a poorly understood and highly modified landscape. Here we present results from three sediment cores collected along a transect of the marine-terrestrial interface at Head of the Bay, Lyttelton Harbour to describe past environments, and rates and types of changes, in these environments through time. The environmental history is built up from micro-fossil analyses (foraminifera and palynomorphs), geochemistry (micro X-ray Fluorescence), geochronology (lead-210 and radiocarbon dating) and sedimentology (granulometry and sediment classification) to decipher natural and anthropogenic changes in land use, shallow water marine environments, vegetation cover, and erosion processes in the middle to late Holocene.

Coccolith productivity variations during the Holocene: influence of the NAO in the Mediterranean Sea.

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In this work, we generated two high-resolution multi-proxy reconstructions from the Western and Central Mediterranean (Alboran Sea and South Adriatic Sea, respectively) over the Holocene period, using calcareous plankton assemblages and biomarkers. The two deep-sea marine cores analyzed (ODP-976, 1108 m wd, in the Alboran Sea and ND14Q-AR2, 1013 m wd, in the South Adriatic) are located in well-known climate-sensitive locations: the Alboran Sea, influenced by water exchange between Surface Atlantic Water and Deep Mediterranean Water, and the Adriatic Sea where river runoff and discharge of the Po River have a strong impact. These paleoclimatic proxies register, in high details, local/regional environmental changes that are driven by variations of atmospheric and oceanic circulations. Coccolithophore assemblages at both sites clearly show orbital-scale variations and short-term centennial scale variability known as Holocene Rapid Climate Changes (HRCC), that superimpose over the main trend. The comparison with several marine and terrestrial proxies allows us to interpret these hydrological variations as the result of atmospheric circulation forcing. In particular, in the Alboran Sea, short periods of increased productivity occur when Atlantic water inflow is stronger, accompanied by more arid conditions on land. In the Adriatic Sea, on the other hand, coccolithophore assemblages and terrestrial biomarker abundances are linked to increased humidity and flood activity in the Alpine region. In both cases the observed variability seems to be related to the North Atlantic Oscillation (NAO). Overall, our results underline the ability of calcareous plankton and biomarkers to capture high frequency environmental fluctuations in the Mediterranean Sea.

Ostracod faunal assemblage response to palaeohydrology, lake-level changed and carbon cycling in a Jamaican marl lake

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Ostracods are small, generally benthic or epibenthic, aquatic crustaceans, which produce low-Mg shells that are often well preserved in Quaternary lake sediments. Fossil lacustrine ostracod species assemblages have variously been used to reconstruct temperature, hydrochemistry, water depth and hydrological habitat and ostracod-shell calcite is use for geochemical analyses in palaeoenvironmental reconstruction. In lakes, the full potential of ostracods as palaeoenvironmental proxies may not be realised owing to incomplete information about the ecological tolerances of species in assemblage and limited knowledge of the workings of the modern lake. Here, we show using a study of Wallywash Great Pond, Jamaica, how the use of ostracod assemblages as proxies for lake-level and hydrology can be improved by using complementary palaeohydrological information and by an understanding of modern limnology of the lake modern ostracods from Jamaica. Wallywash Great Pond is a small (area=76 ha, maximum depth=5 m) karstic lake in SW Jamaica. Previous work on late Pleistocene sediments from the lake suggested that changes in facies and ostracod assemblages reflected variations in lake level in response to precipitation-evaporation balance. More detailed, higher resolution investigations of sediments from the common era show that although previous interpretations are generally true, there is greater subtlety in the reading of the record when evaluated with oxygen and carbon isotope data and modern limnological investigations. Ostracod assemblages and sediment type (organic mud to marl) suggest deepening of the lake midway through the sequence, around 800 CE. However, this seems at variance with stable-isotope data, which may suggest a switch to lower precipitation-evaporation (P-E) balance. Taxonomic uncertainties associated with the dominant deepwater species can be ruled out as an explanation of the discrepancy based on modern collections In Jamaica. Instead, supposed shallow-water taxa are associated with more organic-rich sediment and lower oxygen-isotope values. Distribution of ostracods and sediments in the modern lake suggest that the organic-rich sediments represent greater inflow of groundwater that is undersaturated with respect to calcite under wetter conditions rather than lower P-E. Our findings illustrate the importance of modern limnological and multiproxy investigations in the interpretation of ostracod faunal records from shallow lakes.

Late Holocene transition from natural to anthropogenic forcing of vegetation composition and fire regimes in the western Nanling Mountains, subtropical China

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Understanding the response of forest vegetation to climate, fire regimes and human disturbance is crucial to provide valuable insights to protect current and future ecosystems. However, such studies were poorly carried out for the montane areas of subtropical East Asia with large forests. In this study, we examined pollen and charcoal records of a 95 cm–long peat core from the Daping swamp in the western Nanling Mountains in subtropical China, in order to assess the regional vegetation and fire history and discuss the possible interactions among vegetation, fire, climatic change, and human activities in late Holocene. Our results indicate that the vegetation dynamics and fire regimes were mainly controlled by climate change with minor human disturbance during 3140–2230 cal yr BP. After ~2000 cal yr BP, the residents expanded to deep montane areas and engaged in hunting and logging as their survival strategy, while no strong evidence of farming was detected. The sharp increase in charcoal concentration after 630 cal yr BP suggests a large scale of human activities from the lowland to the higher montane areas, probably due to the official plan to develop terrace land for agricultural use and the rapid population growth since the Yuan Dynasty, which agrees well with the observed vegetation shift from dense forests to more open landscape. Our results strongly show 630 cal yr BP marked the important transition timing from natural to anthropogenic forcing of vegetation composition and fire regimes in the western Nanling Mountains, subtropical China. Regional comparison of charcoal records reveals that human disturbance in the montane areas was significantly intensified later than that of the coastal areas in southeast China. This spatial asynchronized timing and extent of human activity intensity in subtropical south China was likely related to the development of agriculture, as well as to the increase of population and migrations in Chinese history.

Phosphate oxygen isotopes: a palaeoenvironmental proxy from lake sediments

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Understanding controls on regional nutrient dynamics is not just fundamental for combatting modern pollution but also to untangle drivers and consequences of past environmental change. Like nitrogen (N), phosphorus (P) is a limiting nutrient in many systems, including tropical soils, which support highly productive and diverse ecosystems. How P has cycled within the environment over time may therefore exert a critical influence on regional biological diversity and productivity. Where detailed study into the life cycle of carbon (C) and N has been facilitated through stable isotope tracing, P research has been restricted as it only has one naturally occurring stable isotope. Here we explore the potential for utilising the oxygen (O) isotope composition of phosphate (PO_4) within lake sediments to trace temporal variations in P sources and cycling over time. We use sediments from Bulusan Lake (Philippines) as a show case of this approach. Previous work showed variable trace element concentrations (including P) and vegetation productivity markers over the last 1,400 years, linked strongly to regional volcanism. Initial evidence from stable phosphate oxygen isotope analysis of the lake sediments indicates that whilst volcanism could be thought to have an immediate soil fertilisation effect through the addition of P rich ash, this effect is at first limited by an associated reduction in soil pH. Reductions in soil pH cause P to become bound to Fe and Al, reducing P solubility and initially limiting bioavailability of this new source of P. However, in the years following ashfalls it is clear from the stable isotope data that mineral P from volcanic ash is released and cycled. Vegetation productivity indicators are strongly linked to P over longer time scales within the Bulusan record; indicating that this volcanic P addition may act as a fertiliser for surrounding nutrient poor soils and the rich rainforest ecosystem they support.

Session 15: Understanding regional and global monsoons changes across timescales

Upper ocean thermal state and monsoon rainfall

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Monsoon reconstructions suggest that same forcing mechanisms result in a nonuniform spatiotemporal rainfall response. Modelling efforts are critical to understand the competing impacts of different forcings on rainfall and support a substantial regional character. However, simulating past rainfall changes remains a difficult task particularly in the tropics, where models show a large spread in regional rainfall amount and differ from reconstructions. Upper ocean temperature (UOT) is one of the main sources of uncertainty when simulating past and future monsoon rainfall. To decipher the coupling between UOT and monsoon rainfall, particularly under warm climatic conditions, we combine a network of proxy-based reconstructions of UOT and rainfall from the Australasian monsoon realms with numerical model simulations. We show that the thermal state in the upper 200 m of tropical oceans is more sensitive to insolation gradient, rather than ice volume changes, and is critical for changes in monsoon precipitation on interannual to orbital timescales. Equilibrium simulations suggest that the upper tropical ocean acts not only as a moisture source but also as an amplifier of relatively small changes in the forcing, thereby regulating the global hydrological cycle.

Subdecadally resolved molecular proxy-based sea surface temperature reconstructions from the northeast Arabian Sea and implications for the Indian monsoon strength between 11,000 and 2,000 years BP

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Coupled land-ocean-atmosphere interactions play a crucial role in climate variability on all time scales. Among these interactions, monsoons are one of the most important phenomena in low latitudes. The Indian monsoon rainfall has a direct effect on the livelihoods of two billion people in the Indian subcontinent. However, monsoon dynamics on short time scales and their forcing mechanisms are still not fully elucidated.

Sea surface temperature (SST) variability from the northeast Arabian Sea is determined by the intensity of winter monsoon strength on centennial to millennial time scales, where stronger monsoon causes lower SST, and vice versa. In order to constrain high-resolution changes in monsoon intensity and its forcing mechanisms on decadal time scales, we reconstructed SST from the northeast Arabian Sea using alkenone- and GDGT-based SST proxies with a spatial resolution of 200 μm. Such resolution was obtained by applying mas spectroscopy imaging on sediment from finely laminated sediment core SO130-289KL (23°07.34′N, 66°29.84′E, 571 m water depth).

The 200 μm spatial resolution translates into a temporal resolution from 1 to 5 years, resulting in the first continuous subdecadally resolved SST record from the low latitudes between 11,000 and 2,000 years BP. In this presentation, we will examine the dominant periodicity from the SST time series in the multidecadal and centennial time bands. Moreover, we will constrain the decadal to centennial amplitude of proxy-based SST variability, and asses its implication for the Indian monsoon intensity. Ultimately, we will examine the decadal to the centennial phase relationship between alkenone- and GDGT-based SST proxies. This will allow testing the previously proposed hypothesis that when alkenone- and GDGT-based SST proxies are in anti-phase, the northeast Arabian Sea expresses stronger Indian monsoon, and vice versa.

Long-term and short-term vegetation responses of the central Cerrado to climate and anthropogenic activities during the Holocene

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The principal objectives of this study were to evaluate the different responses of the association between vegetation, fire and climate of the central Cerrado under both natural and anthropic disturbances during the Holocene. Our study area is located in Central Brazil, Lake Feia close to the capital Brasília. To reach our goals, vegetation, climate changes, and fire activity were reconstructed using pollen and macrocharcoal deposited in a sediment core from a lake and the chronology was based on accelerator mass spectrometry radiocarbon analyses. Additional XRF analysis was used to determine changes in sediment. Our results showed full development of the Cerrado vegetation in central Brazil started 6000 years ago and followed a two-step process. A long-term influence driven by the increase in summer insolation showed first an open cerrado replaced after 5000 cal yr BP by a woody cerrado. A short-term millennial-scale variability since 4830 cal yr BP that includes 7 intervals of retreat and expansion of the gallery forest due to local changes in hydrological conditions under a continuous fire activity with two extreme peaks at 3340 and 1290 cal yr BP. We conclude that vegetation changes at lake Feia provide evidence about the sensitivity of the Central Cerrado to climate conditions and human inferences. During the Late Holocene, the frequent shifts in northern and southern SASM boundaries drove the expansion and regression of the different floristic assemblages of the Cerrado. A continuous biomass burning under a low fire regime was abruptly interrupted by two intervals of higher fire activity during moist climatic conditions and likely related to human settlements in the region of Lake Feia reinforcing the regional archeological studies.

Multi-decadal to centennial scales variability in the East Asian Summer Monsoon around the 5.5 kyr B.P. climate event

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Understanding the variability in mid-Holocene climate on multi-decadal to centennial scale, including the well-known "5.5 kyr" cold event, is important to better evaluate the East Asia Summer Monsoon (EASM) change under increasing global warming scenarios. In the last few decades, stalagmite oxygen isotope records have been widely used as a proxy of EASM, however, most of high-resolution stalagmite records are from southern China. In this study, a four-yr resolved $\delta^{18}O$ record of a stalagmite TW704 from north-eastern China was used to reconstruct regional precipitation and EASM from 5.82 – 4.77 kyr BP (before 1950 AD). The inferred EASM variation generally agrees with previous published stalagmite records from southwestern and central China, suggesting synchronous variations of the EASM on decadal to centennial scale in monsoonal China. Our new record also features relatively large decadal-centennial EASM oscillations in the northern China with two centennial-scale weak EASM events, centred at 5.6 and 5.0 kyr. The former one corresponds to the well-known "5.5 kyr" cold event occurred in the high-latitude North Atlantic Ocean. The depressed EASM events were probably caused by prolonged periods of El Niño, resulting in decreased precipitation over north-eastern China. Our study supplies robust evidence to support the hypothesis that ENSO plays an important role in the EASM during the mid-Holocene.

Asynchronous Holocene Optimum in East Asia monsoon region recorded by stalagmites and its underlying climate dynamics

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Reconstructions of Holocene Optimum (HO) in East Asian summer monsoon (EASM) regime from speleothem versus other proxy records have yielded divergent phase relationships with the EASM and local precipitation. This apparent discrepancy has been partly attributed to the uncertainties in the climatic representation of Chinese speleothem oxygen isotope (δ^{18}O) records. Here we conducted a data-model comparison along with a water moisture budget analysis to assess the role of thermodynamic and dynamic components in controlling mid-summer and spring rainfall during early and mid-Holocene, and to compare with the precipitation changes referred by the stalagmite δ^{18}O records. Our results show that 1) a marked southward shift of the HO period from 10000~6500 yr BP in North China (NC) to 9000~5500 yr BP in Yangtze river valley (YRV). During the Holocene, the variation of the summer total precipitation is dominated by precession in NC, ice sheet in YRV. 2) An incoherent orbital-scale speleothem δ^{18}O variability in EASM regime indicate that speleothem δ^{18}O is largely controlled by the large-scale circulation and concomitant latitude shifts of monsoon rain belt.3) The intensified hydroclimate in YRV in mid-Holocene was contributed to excessive rainfall in summer, especially for increasing the convection/total precipitation ratio, which leads to the lightest speleothem δ^{18}O during the mid-Holocene. The excessive rainfall in summer mainly from the enhancement of convective activities that is caused by the southward shift of monsoon rain belt.

Simulated Air-Ocean interaction in the western North Pacific since the Last Glacial Maximum

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1. The Kuroshio Current affects the modern sea level and brings warm and salty water to the marginal seas of the midlatitude East Asia. Since the Last Glacial Maximum (LGM), while the proxy data suggest the subarctic control in the Kuroshio Extension (KE) region during cold intervals, it is not yet clear what specific role played by air-ocean interaction in the vicinity of the western boundary current most efficiently caused such distinction from the present condition.
2. Here, we examine the simulated air-ocean coupled variability in the Kuroshio and the Extension region during the LGM and the mid-Holocene using Paleo Model Inter-comparison Project 4 data archives.
3. Especially, the variability in the meridional location and axis orientation of the north hemispheric Westerly jet associated with the paleo-Arctic Oscillation under such contrasting mean states across the multi model simulations. In addition, for selected models with high enough temporal resolution outputs, storm track activity is analyzed for the two different climate periods in comparison with the present.
4. Finally, the mean and the variability of the simulated Kuroshio with different models are assessed for the contrast under both the LGM and the mid-Holocene climates.

Spatially heterogeneous responses of climate in East Asia to insolation, CO2 and ice sheets during MIS-5

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Marine Isotope Stage (MIS) 5, lasting from ~130 to ~70 thousand years before present (ka BP) , is characterized by climate oscillations consisting of three interstadials and two stadials. Many climate simulations have been performed for the warmest MIS-5e period, but few has been made to cover the entire MIS-5 to investigate the climate variability during this long period. To study the relative impacts of insolation, CO_2 and Northern Hemisphere ice sheets on the internal variations within MIS-5 and spatial variations of the East Asian climate, two sets of snapshot simulations with different combinations of forcings by a step of 2 ka covering the whole MIS-5 period are performed with HadCM3. Moisture budget analysis is carried out to investigate the processes related to changes in summer precipitation. Our results show that EASM climate in different subregions have different sensitivity to astronomical forcing, CO_2, and ice sheets. The variability of temperature and precipitation within MIS-5 is mainly controlled by precession with strongly pronounced sub-stages of MIS-5 which correspond to precession minima and maxima, but their magnitudes are modulated by CO_2 and ice sheets. Within the range of its variations during MIS-5, the CO_2 concentration can cause similar degree of warming as insolation. However, the influence of CO_2 on precipitation is much weaker than the influence of insolation, and the relationship between summer precipitation and CO_2 is not statistically significant in most subregions in East Asia. Insolation and CO2 affect the summer precipitation by the dynamic and thermodynamic processes, respectively. Although ice sheets induce large cooling in the mid-high latitudes of both hemispheres, their impact on the precipitation and temperature in East Asia is quite small as compared to the impact of insolation, varying between regions and sensitive to the area and height of the ice sheets and the background insolation. Ice sheets influence the EASM precipitation mainly through the vertical dynamic processes which is strongly associated with the ice sheet-induced wave train at the hemisphere scale.

Primary productivity variability in the Northwestern Arabian Sea since the Last Glacial Maximum : A significant role of mineral dust inputs

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The Arabian Sea (AS), located in the Northwestern part of the Indian Ocean, is surrounding by desertic regions (e.g. Arabian Peninsula, Pakistan) and thus, receives important amounts of mineral dust through regional winds. This oceanic area is also under the influence of Indian monsoon surface winds that create a coastal upwelling off Somalia and Oman during summer and a convective mixing north of 15°N during winter. Mineral dust, coastal upwelling and convective mixing bring important amount of nutrients to the euphotic zone and make the AS, one of the most productive oceanic regions in the world. Numerous studies of the imprint of primary productivity (PP) in the AS in the past show the significant influence of nutrient inputs from the coastal upwelling. However, a recent study based on the analysis of coccoliths from sediment core MD00-2354 (61.48°E, 21.04°N; 2740 mbsl), and the use of Earth System models, demonstrates that convective mixing and probably mineral dust inputs might have a major influence on PP in the northwestern AS since the Last Glacial Maximum (LGM). As this time interval encompasses a glacial-interglacial transition with rapid fluctuations of ice sheet volume and atmospheric CO_2 concentration, it is therefore a perfect case study to explore the impact of key Earth's climate forcing mechanisms on the PP of the AS for both, past and future climate conditions. Yet, mineral dust component is still poorly documented by data in the AS, which limit interpretations of their influence on PP. Based on a multi-proxy characterization of the marine core MD00-2354 that combines detrital fraction grain-size distribution, clay mineralogy composition as well as bulk geochemical composition, we provide for the first time, a high-resolution (~200 yrs) eolian signal in the Northwestern part of the AS since the LGM. Preliminary results indicate millennial changes in atmospheric conditions as well as dust emission/deposition capacity in the area in coherence with previous low-resolution eolian records. The comparison of the newly obtained eolian signal with the high-resolution PP signal obtained on the same site indicates a significant role of mineral dust inputs on PP since the LGM.

Changing positive to negative temperature-moisture relationship at the start of the Holocene predicts future drying of East Africa

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Characterized by national economies which rely heavily on crop agriculture and highly variable annual rainfall from year-to-year, East Africa is endemically vulnerable to water scarcity. Whereas future climate projections for the region predict increased rainfall during the 21st century as global temperatures continue to rise, meteorological observations record a trend towards drier conditions in the recent decades. Paleoclimate reconstructions have a clear role to play in understanding the stability of the relationship between temperature and moisture balance across a large range of climate states and in elucidating how this may develop over the next decades to centuries. However, there is generally a shortage of climate proxy records from continental low-latitude settings which are both long and detailed. We analysed glycerol dialkyl glycerol tetraethers (GDGTs) in the continuous and depositionally uniform sediment record of Lake Chala (Kenya/Tanzania) to provide the first paired temperature and hydroclimate reconstruction from equatorial East Africa spanning Marine Isotope Stages (MIS) 4 through 1. Our record shows that the Heinrich-1 megadrought period (~18,000-15,000 years ago) was both the driest and coolest episode in the last 75,000 years. Contrary to most low-latitude regions worldwide, the Last Glacial Maximum was fairly wet by comparison, continuing the wet conditions which prevailed through most of MIS4 and MIS3. Temperature and moisture balance in easternmost Africa both responded strongly to orbital precession but also show a significant obliquity signature. Moisture balance also shows the so-called half-precessional cycle (~10,500 year), typical of regions in the heart of the tropics, where the sun passes overhead during both the vernal and autumn equinoxes. The long-term positive relationship between continental moisture balance and temperature during the last glacial period switched to negative at the start of the Holocene 11,700 years ago, indicating that when atmospheric CO_2 exceeded 250 ppmv a tipping point was crossed linked to the opposing influences of elevated temperature on monsoonal precipitation and continental evaporation. Our results imply continued climatic drying in eastern equatorial Africa and diminishing future water resources, notwithstanding climate-model projections of increasing rainfall.

Reconstructing the role of temperature changes in determining the glacial-interglacial aridity variability in tropical regions

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Considerations of past climate change in tropical regions focus primarily on precipitation, as variability in rainfall seasonality and amount is much stronger than that of temperature. While hydrological changes at most timescales are unquestionably large, and likely important drivers of tropical environmental changes, recent reanalysis of several pollen records from southern Africa and South America using the probabilistic pollen-based climate reconstruction method CREST (Climate Reconstruction SofTware) has highlighted the strong imprint of temperature variability on vegetation, with, for example, the influence of lower temperatures and evapotranspiration on water availability compensating for reduced precipitation during the Last Glacial Maximum. This highlights that at some timescales – such as glacial-interglacial cycles and transitions, when temperature changes are large – temperature changes have the potential to modulate and even balance the impact of precipitation changes. Similar results have also been observed from some of the PMIP3 climate simulations, which further highlighted that the intensity of this 'temperature effect' on aridity (precipitation minus potential evapotranspiration) varied spatially and depended on the background level of local precipitation. Since many palaeoclimate records representing aridity are commonly interpreted primarily in terms of changes in rainfall amount, the potential exists for a misinterpretation of these records. In this talk, we demonstrate that (co-)quantifying past temperature, precipitation, and aridity changes across the tropics and subtropics can be critical for understanding where and when the 'temperature effect' is most prevalent and, subsequently, for achieving a more comprehensive understanding of past monsoon dynamics.

Drivers of Australian-Maritime Continent monsoon changes in PMIP simulations of mid-Holocene and Last Glacial Maximum climate

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The Australian-Maritime Continent monsoon (also known as the Indo-Australian monsoon) is a complex regional monsoon which is influenced by both local and remote drivers on a range of time scales. Future projections under global warming indicate strong agreement between climate models on an increase in monsoon precipitation over the Maritime Continent but low agreement on the direction of change over northern Australia. We examine the Australian-Maritime Continent monsoon in simulations of mid-Holocene (6 ka) and Last Glacial Maximum (21 ka) climate from the latest set of Paleoclimate Modelling Intercomparison Project (PMIP) global climate models. Model simulations are compared with available proxy records from the region. The mid-Holocene simulations demonstrate strong model agreement on the response of the monsoon to reduced Southern Hemisphere summer insolation and increased insolation in the pre-monsoon season. The Last Glacial Maximum simulations produce a more complex response, with less model agreement. Changes in seasonal heating and moisture transport due to the expanded continental shelf interact with dynamic and thermodynamic responses to global cooling and regional changes in temperature gradients.

Timescale dependent fingerprint of the East Asian Summer Monsoon during the last Glacial and its interaction with vegetation

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The East Asian Summer Monsoon (EASM) is fundamental for the water supply of more than a billion people in East Asia. It has undergone major changes during the Pleistocene. It varied nearly synchronously with orbital-scale insolation and millennial-scale warming and cooling events in the North Atlantic which are associated with abrupt changes in the Atlantic Meridional Overturning Circulation (AMOC). Yet, the spatial fingerprint of these variations and their interaction with local vegetation remain uncertain. Here, we present vegetation and climate reconstructions from a pollen record in Northeastern China covering the last 70kyr with unprecedented sub-centennial resolution. Today, the site is located at the northernmost edge of the EASM. During the last glacial, its position at the ecotone between cool mixed forest and steppe led to a pronounced imprint of past climate changes in the local vegetation. We show that vegetation changes are likely driven by hydroclimate changes and occurred synchronously with water isotope variations in Chinese speleothems. However, the ratio of orbital- over millennial-scale vegetation variations is three times higher than in the isotope record. While carbon dioxide changes likely amplified orbital-scale vegetation variations, this suggests that orbital- and millennial-scale variations of the EASM possess different spatial fingerprints: insolation and greenhouse gas forcing leads to strongest changes in the northern monsoon domain while AMOC changes manifest mostly in the southern monsoon areas. Accurate simulations of these fingerprints are important for future water EASM projections under increasing greenhouse gas concentrations and potential AMOC weakening.

Reconstructing temperature variability of monsoonal East Asia using branched tetraether membrane lipids and clumped isotopes of land snail shells in the Chinese Loess Plateau over the past 75,000 years

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Our understanding of (past) East Asian Monsoon (EAM) climate variability and its drivers is still under development. For example, past variations in EAM strength recorded by speleothem $\delta^{18}O$ shows a strong link with precession, whereas those reflected by magnetic susceptibility records from the Chinese Loess Plateau (CLP) additionally contain a strong glacial-interglacial fluctuation. Although both records are generally assumed to reflect variations in East Asian Summer Monsoon (EASM) precipitation, the discrepancy in orbital forcing suggests that speleothems and magnetic susceptibility actually record different aspects of EAM climate.

Here, we aim to identify a possible temperature component in loess-paleosol sequence by reconstructing a continuous, high-resolution, absolute temperature record for the past 75,000 years, for which we use temperature-sensitive soil bacterial membrane lipids, so-called brGDGTs, and clumped isotopes (expressed as Δ_{47}) of land snail shells stored in Yuanbao section on the western edge of the CLP.

Our two independent temperature records show the same variability over the past 75,000 years, albeit with an offset in their long-term trend. However, the temperature records do not reflect the same clear millennial scale and glacial-interglacial variability that is recorded by magnetic susceptibility in the same sequence. The distinct trends of these records can be explained if our temperature proxies primarily record summer temperatures, which might be linked to low latitude climate processes through the EASM, and magnetic susceptibility represents a more annually integrated climate signal that also involves high latitude processes. This scenario would imply that high latitude processes are a more important control on EASM precipitation variability than temperature on the CLP.

Millennial- and orbital-scale drivers of Australia's hydroclimate during the Last Glacial Period: insights from subaqueous speleothems

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While initiated in the NH, recent evidence suggests that the abrupt climate events of the Last Glacial Period were propagated across the globe in a matter of decades. The influence of these events on monsoonal systems is well-established across China and other parts of East Asia where abrupt North Atlantic cooling was accompanied by weakening of the monsoon. Conversely, these events appear to have coincided with a stronger South American monsoon. Though few and far between, some studies suggest that the Indo-Australian Summer Monsoon and Southern Hemisphere Westerly Winds also experienced substantial displacement during the LGP in response to cooling in the North Atlantic.

Lying on the boundary between tropical and mid-latitudinal climate systems, Mairs Cave (South Australia) is perfectly positioned to provide insight into migrations of the IASM and SHWWs. The cave contains pendulites: stalactites with an external overgrowth of subaqueously precipitated calcite. The stalactites in Mairs Cave were initially submerged by ~ 89 ka by rising groundwaters, which partially flooded the cave. From that point forward, the pendulites grew subaqueously during periods of regional groundwater recharge and lay dormant during comparatively dry periods when the water table receded.

Preliminary growth rate and trace element results from two pendulites from Mairs Cave appear to support the theory that the IASM and SHWWs experienced southerly displacement in response to millennial-scale cooling in the North Atlantic. Meanwhile, hiatuses in pendulite growth coincide with minima in SH summer insolation, suggesting that Australian rainfall patterns are also governed by the position of the IASM on orbital time scales. The significance of these results are two-fold: not only do they provide insight into global climate dynamics during the Last Glacial Period, but they also provide a climatic contextualisation for the expansion of humans across the continent, which heralded the beginning of the world's oldest continuing culture.

East Asian Monsoon evolution during glacial terminations I and II at Lake Suigetsu, Japan

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The East Asian Monsoon – constituting summer (EASM) and winter (EAWM) modes – is a critical component of the global climate system, driven by semi-annually reversing temperature gradients between Continental Asia and the Pacific Ocean. Understanding East Asian Monsoon behaviour during periods of warming is now critical, in light of recent anthropogenically-driven climate change. A network of high-quality records of palaeomonsoon evolution are key to our understanding of the underlying dynamics of this system. The two most recent glacial terminations (TI, 22–10 ka and TII, 136–124 ka) are amongst the best-preserved examples of warming periods in the Pleistocene, however, there are limited records available for these intervals and in most cases seasonal contributions remain unresolved.

Japan is ideally situated to detect changes in East Asian Monsoon behaviour because it is located beneath the seasonally migrating monsoon front and between two water bodies, which results in heavy precipitation during both EASM and EAWM seasons. Here we present records of EAWM behaviour across TI and EASM behaviour across TI and TII derived from analysis of the Lake Suigetsu sediment cores (Fukui Prefecture, Japan). These cores contain information from the present day to >160,000 yr BP, and hence offer a rare opportunity to study both TI and TII at high precision in the same high-quality terrestrial archive. Oxygen isotope analysis of diatoms and hydrogen isotope analysis of biomarkers were used as proxies for monsoon precipitation at a centennial (TI) to bicentennial (TII) resolution.

This bi-proxy approach establishes the similarities and differences between winter and summer monsoon evolution across glacial terminations. Additionally, the excellent chronology for the Suigetsu sediment cores facilitates comparison of our records to global benchmark records (e.g., ice cores, speleothems) outside the monsoon region. This permits investigation into cross-continental teleconnection relationships and provides vital contextualisation of East Asian Monsoon intensity in the global picture of climatic rearrangement. We observe time-dependent influences of both Northern Hemisphere and Southern Hemisphere climatic patterns on our records, related to the changing position of the monsoon front.

Exploring Late Quaternary African Humid Periods from Saharan dust deposits off West Africa

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Through the Quaternary, variations of insolation received over Africa have governed the monsoon dynamics in this region, generating a recurrence of intense rainfall periods. These African Humid Periods (AHP) are characterized by a major transformation of the Saharan hydrological cycle, favouring the development of vast fluvial systems and tropical humid ecosystems in the currently hyper-arid Sahara Desert. In the present-day context of global warming, understand the environmental mechanisms and responses associated with these dramatic swings between two extreme hydroclimatic states appears crucial in order to improve climatic projections of these vulnerable areas. In this study, we propose to originally reconstruct AHP by studying the Saharan dust deposited in sediments of the Northeastern Atlantic Tropical Ocean. In fact, past modifications of Saharan dust deposited off West Africa, in addition to retrace atmospheric circulation changes (wind intensity and direction), indirectly reflect Saharan hydrological cycle variabilities (dust sources availability, aridity). Here, we present a high-resolution (1 sample/200yrs) multi-proxy characterization of the Saharan dust deposited continuously through the last 240ka - a period punctuated by eight AHP - in the marine core MD03-2705 (18°05N; 21°09W; 3085 mbsl). We combine dust flux, grain-size distribution, clay mineralogy and geochemical compositions in order to explore changes in the Saharan hydroclimate and atmospheric circulation over North Africa on orbital timescales, with a particular focus on the mechanisms associated with the recurrence of the AHP.

Seasonal bias introduces distinct signatures in monsoon records from inorganic and isotopic proxies in loess

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Based on paleoreconstructions of the East Asian Monsoon (EAM) climate, the intensity of summer precipitation associated with the EAM is presumed to strengthen in response to ongoing warming. Most reconstructions are based on oxygen isotopes ($\delta^{18}O$) of cave speleothems and on grain size (GS) and magnetic susceptibility (MagSus) in Chinese loess sequences. Strikingly, the speleothem $\delta^{18}O$ records is dominated by precession signal, and lacks glacial-interglacial change, which argues for a strong control through changes in summer insolation. The MagSus and GS in the loess show a glacial-interglacial pattern that strongly resembles the amplitude and structure of deep sea oxygen isotope records, which in turn suggests a strong relationship with ice volume and global climate change.

To further investigate the distinct cyclicities in the speleothem and loess proxy records, we here generate a 140,000 year long record of plant wax hydrogen isotopes (δ^2H_{wax}) for the Yuanbao section on the western Chinese Loess Plateau. δ^2H_{wax} and speleothem $\delta^{18}O$ both reflect the isotopic composition of rain water. δ^2H_{wax} is analyzed for the same loess section as the GS and MagSus proxies thus allowing to directly compare all records. Like the speleothem $\delta^{18}O$ record, δ^2H_{wax} does not exhibit a strong glacial-interglacial variability, but is instead dominated by changes at precession and millennial scale variability. We suggest that the isotopic signal in the precipitation is linked to the summer season, as the plant wax signal is generated during the growing season. Similarly, the $\delta^{18}O$ of the speleothem record represents a summer signal as suggested in previous studies. The large glacial-interglacial amplitude in the MagSus record and its strong link to global ice volume could in turn be related to the length of the summer season, and thus a yearly integrated climate signal in these records. The amplification of winter cooling during globally cool periods with large ice volume is consistent with sea ice and snow cover feedbacks.

Middle to Late Quaternary TOC data from a Japan Sea sediment core MD01-2407, a long archive of the Arctic climate beyond the Greenland ice cores

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The Japan Sea is a semi-closed marginal basin located between the east Eurasia Continent and the Japanese islands, connected to the open seas through the four straights shallower than 140 m in sill depth. This topographic feature implies that the eustatic sea level change has a significant affect on the input of open sea water and the circulation of deep water in the basin in the geologic time. For the past 650 ka, we measured total organic carbon (TOC) and total nitrogen (TN) contents of a sediment core MD01-2407 recovered from the Oki ridge in the southern Japan Sea to reveal a high-resolution history of the biological productivity in relation to the global climate change, at 1 cm interval (~130-year interval on average).

Except for the interglacial ages *in sensu stricto*, the TOC profile illustrates a unique quasi-periodic fluctuation with high TOC contents in the warmer periods and low TOC contents in the cold/cool periods in the majority of cases (~90% of the total periods). The TOC fluctuation patterns consistent with a sea level curve LR04 on a longer time scale, and those in the glacial ages of 10-110 ka BP are very similar to the delta^{18}O profiles of the Greenland ice cores such as NGRIP on time scales of Dansgaard-Oeschger events. This result suggests that the TOC profile of the Japan Sea provides an older Arctic climate record in the glacial ages beyond the time interval covered by the Greenland ice cores, potentially serving a regional stratigraphic standard for the middle to late Quaternary in East Asia. The TOC content in the offshore sediments is controlled by a delicate balance between biological productivity in the euphotic zone and organic matter decomposition in the water column. Moreover, the position of the Arctic polar front migrates in connection with the global climate change, influencing nutrient availability by deep water upwelling and decomposition potential by oxygen supply in the water column. A scenario which explains how the Arctic climate controls TOC content in the Japan Sea will be detailed in the presentation.

100-kyr pacing of the East Asian summer monsoon over the last five glacial cycles inferred from land snails

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The East Asian summer monsoon (EASM) transports moisture from the tropical Indo-pacific to the boreal, which constitutes the primary rainfall for the East Asia area and greatly influences regional hydrological conditions. The prevailing of the EASM is commonly thought to be mainly influenced by the orbital forcing and the effects of orbital forcing on the EASM after the Mid-Pleistocene transition are controversial. Different climatic proxies have different cycles, for example, Chinese cave δ18O records only show low-latitude ~20-kyr cycles, while pedogenic proxy records from Chinese loess are dominated by high-latitude 100-kyr cycles. This discrepancy may result from the multi-component origin of proxies, particularly for pedogenic signals in loess deposits, with the primary climatic signals modified by pedogenic smoothing, leaching, and changes in sedimentation rate. In this study, we used the carbon isotopic composition of land snail shells (δ13Cshell) in the loess deposition as an indicator of precipitation, which record the past 470 kyr EASM fluctuation in the central Chinese Loess Plateau. δ13Cshell is well correlated with magnetic susceptibility and δ13CIC (carbon isotope composition of carbonate) on orbital timescales, showing pronounced 100-kyr glacial-interglacial cycles, with more depleted values during inter-glacial compared to glacial periods. Cross-spectral analysis furtherly shows the δ13Cshell was coherent with pedogenesis proxies (especially magnetic susceptibility), within the eccentricity band (~100-kyr), suggesting that, like pedogenesis proxies, the δ13Cshell record variations of EASM precipitation. The absence of a precession signal in our records suggests that δ13Cshell is not significantly influenced by the sedimentation rate and that it exclusively captures the dominant 100-kyr signal of monsoon precipitation. Overall, δ13Cshell record is highly coupled with high northern latitude ice volume variations, possibly supporting the high-latitude forcing of EASM. We also found that at the end of marine isotope stage (MIS) 11, δ13Cshell-based precipitation remained at an interglacial level following the MIS 11 super-interglacial climate in the Northern Hemisphere, although on a global basis a glacial period had commenced. It is confirmed that the δ13Cshell should sensitively record the key climatic events of the East Asian monsoon.

North African Humid Periods over the past 800000 years – Timing, Amplitude and Forcing

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The Sahara region has experienced periodic wet periods over the quaternary and beyond. The timing of these North African Humid Periods (NAHPs) is linked to astronomically pacing by precession which impacts the position of the African monsoon systems. However, many models do not correctly simulate the magnitude of these events and so the driving mechanisms remain poorly constrained. Here we present an 800kyr climate dataset produced using a convection updated version of the HadCM3B coupled climate model that simulates 20 AHPs over the past 800kyr which have good agreement with the timing of NAHPs identified in proxy data. Precession determines their pacing, however their amplitude is strongly linked to eccentricity via its control over ice sheet extent. During glacials, the thermodynamic effect of increased albedo weakens the West African Monsoon and alters the dynamics of the subtropical westerly jet which inhibits Saharan convective rainfall. This suppresses the amplitude of the NAHPs during glacial periods of precession minima. Our results highlight the importance of both precession and eccentricity, and the role of high latitude processes in determining the timing and amplitude of the NAHPs.

Ice volume and insolation forcing of abrupt strengthening of East Asian winter monsoon during glacial inceptions

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The East Asian winter monsoon (EAWM), a major component of the East Asian monsoon circulation, is characterized by prevailing low-level northwesterly winds tightly linked to the high-northern-latitude climate via the Siberian-Mongolian High.Our current understanding of the EAWM dynamics during the glacial-interglacial cycles is mostly based on loess records on the Chinese Loess Plateau (CLP), which suggest that the EAWM intensity is closely linked to the volume of the Northern Hemisphere ice sheets (NHIS) on orbital timescale. However, unlike the ‘sawtooth’ pattern of global ice volume that shows a gradual build-up of the ice sheets (in ~9000 years) followed by rapid deglaciation (in ~1000 years) since the middle Pleistocene transition as documented by the benthic $\delta^{18}O$ records, the loess records of EAWM show distinct glacial and interglacial modes, with the transitions between them generally being quick. This dissimilar evolution pattern between the EAWM and the global ice volume (and NHIS) at the interglacial-glacial transitions means that some key information is missing regarding the dynamics of the EAWM during the glacial inceptions. By generating an independent chronology framework and integrating multi-proxy records from the loess sections on the central CLP, here we show that the rapid intensifying of the EAWM during glacial inceptions, previously demonstrated as a direct response to the build-up of NHIS, actually reflects millennial perturbations in the large-scale atmospheric circulation in East Asia caused by insolation-triggered abrupt North Atlantic cooling when NHIS reaches a critical large size. The role of NHIS is reinterpreted as preconditioning the teleconnection between North Atlantic and East Asia during glacial inceptions instead of directly controlling the intensity of EAWM. Our integrated multi-proxy records thus highlight the key role of ice volume in modulating the response of the EAWM to insolation-triggered North Atlantic cooling during the interglacial-glacial transitions.

North African aridity and humidity variability during the Plio-Pleistocene

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Records of North African climate are essential to get a mechanistic understanding of the link between insolation changes, monsoonal changes, and global climate variability. An established way to reconstruct North African climate and associated monsoon dynamics is by the use of the ratio of titanium to aluminum (Ti/Al) in sediment cores from the eastern Mediterranean Sea. During humid intervals these sediments contain an increased amount of aluminum-rich clays from North African rivers, while during arid intervals these sediments contain more titanium-rich dust from North African deserts. Therefore, high/low values of Ti/Al correspond to arid/humid conditions in North Africa, respectively. Here, we demonstrate how to obtain reliable Ti/Al data using X-Ray Fluorescence (XRF) core scanning; an analytical method that is fast and relatively inexpensive. As such, this method allowed us to produce a 5-Myr North African climate record from eastern Mediterranean Sea sediments (ODP Site 967). This near-continuous timeseries of the North African environment shows that (i) fluvial terrigenous sediment inputs doubled during Green Sahara Periods at ~3.2 million years ago, likely as a result of an abrupt non-linear North African landscape response, (ii) African environmental variability and associated monsoon dynamics were dominantly paced by low-latitude insolation alone to ~1.2 million years ago, and (iii) remote high-latitude climate left especially a notable imprint on North African aridity/humidity after the mid-Pleistocene transition (~1.2-0.7 Ma) when a threshold ice volume was reached during ice ages.

The spatial–temporal evolution of the Asian summer monsoon during the late Miocene and potential CO2 forcing: A data–model comparison

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The long-term evolution of the Asian summer monsoon and its drivers are important for understanding future Asian summer monsoon variations. Due to inconsistencies among proxy data and/or different interpretations, the long-term evolution and drivers of the East and South Asian summer monsoons (EASM and SASM) during the late Miocene still remain controversial. There are two main viewpoints involving an overall strengthening or weakening trend, which is typically attributed to uplift of the Himalaya–Tibetan Plateau or global cooling. Here, we compiled paleoenvironmental reconstructions for the EASM and SASM during the late Miocene and used numerical simulations to investigate their evolution and potential drivers. The synthesized results indicate that the late Miocene climate: (1) underwent an overall drying trend in northern China, but a wetting trend in the South China Sea and surrounding areas; and (2) became progressively drier on the northern Indian subcontinent, but not on the southern Indian subcontinent. The modeling results indicate that: (1) EASM circulation overall weakened, whereas SASM circulation weakened (strengthened) in the northern (southern) part of South Asian monsoon domain; (2) summer precipitation decreased (increased) in the northern (southern) part of East and South Asian monsoon domains, which is roughly agreement with the paleoclimate records. Our results suggest that a decline in atmospheric CO_2 may have been an important driver of the evolution of the EASM and SASM during the late Miocene.

Session 16: Linking paleoenvironmental proxies at different scales: potential, problems and limits

How to combine dental wear and pollen proxies for a better knowledge of past local environments?

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Among the tools used to describe past local environments, those derived from the plant and animal remains are the most powerful. The study of pollen and dental wear in herbivores are commonly used for this purpose. They allow us to reconstruct local plant cover and infer the climatic context. These approaches, however, are rarely combined together. We present here the first study that integrate pollen records from caves and deep-sea cores and dental wear data (meso- and microwear) from archaeological sites.
Pollen spectra from caves reflect the composition of the local vegetation cover contemporaneous with the sedimentary layer from which they originate. Pollen from deep-sea cores gives an integrated image of the regional plant communities with a precision of a few hundred years. Dental wear allows the reconstruction of the animal diet, and in the case of herbivores, the plants available in the area. However, this approach is less detailed than pollen studies since it only discriminates between dicots and monocots. It addresses the local and regional environments through the prism of the sedimentary level but allows us to identify seasonal variations by comparing the dental meso- (a few years) and microwear (a few days) signals.
In addition to increase accuracy and resolution of the local environmental interpretations, the combination of these data could allow 1) improving the interpretation of past environments based on tooth wear by linking macro- and micro-trace patterns as directly as possible to non-analogue present-day plant communities; 2) combining the time scales accessible through the two approaches and detail definition of the amplitude of seasonal variations; 3) defining the specificities of a local environment in relation to regional trends by combining the geographical scales represented by deep-sea and archaeological sedimentary sequences.
Nevertheless, despite this promising perspective, the disparity of the data limits their integration and imposes a methodological questioning. For example, sedimentary layers provide, in comparison with deep-sea cores, imprecise ages. The time-span they cover generally encompasses several of the climatic events identified in the deep-sea cores. At the scale of the site, the different origin of the pollen and the teeth limit their statistical integration.

Multiproxy reconstruction of the Plio-Pleistocene ecological context of ungulates from the Ahl al Oughlam site (Morocco) based on tooth analysis

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The Sahara Desert was not always a natural barrier in the past and it experienced multiple green and humid phases, allowing dispersal episodes of fauna from Sub-Saharian locations to the North of Africa. High-resolution palaeoecological studies are underrepresented for the Plio-Pleistocene in Northern Africa. The aim of this work is to fill this gap reconstructing the paleoecology of the Ahl al Oughlam (AaO) ungulate communities by characterizing their diets and habitats combining two proxies, stable isotopes and dental wear.
AaO is located at the southeastern limit of the city of Casablanca (Morocco) at about 34° North and 105 m a.s.l. The site, rich in small and large vertebrates, is correlated to near the Plio-Pleistocene boundary (ca. 2.5 Ma) based on biostratigraphy of mammals.
A total of 87 samples of tooth enamel from ungulates were sampled for the stable carbon and oxygen isotope analysis and 64 and 45 molars were selected for microwear and mesowear analysis, respectively. These techniques provide dietary information on three different timescales: stable isotopes - first years of animal's life; mesowear - annual average of an animal's life and microwear - last days/weeks of an animal's life.
The carbon isotope results show the predominance of C_3 plants in the diet of all species. The difference in $\delta^{18}O$ between non-obligate and obligate drinkers has been used as a proxy for relative aridity. These differences in AaO taxa suggest an aridity similar to that of today's African savannah. The dental wear results show a wide spectrum of diets. Mesowear indicates low levels of abrasion related to browser diet for *Sivatherium*, *Gazella* and Alcelaphini, and a high level of abrasion related to grazer diet for *Hipparion*. Microwear reveals browse-dominated dietary traits for *Gazella* and *Sivatherium*, and mixed feeding dietary traits for *Anancus*, *Hipparion* and Alcelaphini. Unexpectedly, the AaO Alcelaphini show a dental wear pattern corresponding to a mixed and less abrasive diet than pure grazing diet of the modern Alcelaphini
In conclusion, the combination of proxies highlights niche partitioning among the ungulates recovered at AaO and the availability of different habitats such as open woodland and xeric C_3 grassland.

Dental Wear Analysis: The Diet of Deer and their Pleistocene Palaeoecology

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During the Pleistocene, dramatic fluctuations in climate greatly shaped European environments, determining the available foliage for herbivores to consume. Previous research has identified a wide diversity of dietary signals of Pleistocene deer, with groups that have a stronger grazing signal, a stronger browsing signal, or a mixed feeding diet. Focusing on the later part of the Last Glacial Period, Marine Isotope Stage 3 (MIS 3, ~26-60 thousand years ago (kya)) until the end of the Pleistocene c.11.5 thousand years ago, this study utilises dental wear analysis to elucidate the dietary ecology of reindeer (*Rangifer tarandus*), red deer (*Cervus elaphus*) and giant deer (*Megaloceros giganteus*) from various Late Pleistocene sites. Dental wear analysis is comprised of two methods – dental microwear analysis and dental mesowear analysis. Dental microwear is a well-established technique of examining tooth enamel for distinctive microscopic scars made by certain food groups, which provides high-resolution insights into the organism's dietary behaviour during the final weeks to days before death. Dental mesowear is the macroscopic study of tooth cusp shape and relief, which is formed from the varying forces of abrasion and attrition in a diet over months to years, producing a more general signal of an individual's diet. By applying these methods to Late Pleistocene deer specimens, it can be determined that the dietary ecospaces of deer did not significantly overlap, indicating a degree of niche differentiation. It is further suggested that the disparity between microwear (short-term diet) and mesowear (long-term diet) in reindeer from certain sites may indicate seasonal flexibility in diet and the use of particular sites year-round. Therefore, by increasing our knowledge of species' dietary ecology in the face of past climatic change, we may further improve predictions of current species' responses to the rapidly changing globe.

Multi-proxy dietary reconstruction of derived Equinae from the Miocene through the Plio-Pleistocene of North America

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Dietary proxies with different temporal resolutions were employed to provide a comprehensive dietary reconstruction of North American fossil equid taxa spanning from the late Miocene (Clarendonian) through the Pleistocene (Rancholabrean). Hypsodonty, mesowear and microwear trends were studied on derived Equinae. These results were then compared to three extensive extant ungulate tooth wear databases. Results show that in the early Miocene, derived Equinae underwent a consistent increase in hypsodonty and mesowear scores (abrasion indices) and continued this trend through the Pliocene and Pleistocene but declined slightly in the Recent. A microwear abrasion index, scratch texture, mirrored hypsodonty and mesowear trends, but microwear alone turns over rapidly enough to reveal the actual dietary reason for these shifts in abrasion. In the early Miocene, microwear scratch number results show that hypsodonty and mesowear trends toward greater abrasion were due to the derived Equinae engaging mostly on high-abrasion grass consumption but as grazers and mixed feeders. In the late Miocene, the derived Equinae continued with coarse microwear scratch textures and continued the trend toward engaging in both grazing and mixed feeding. This dietary trend continued into the Pliocene, but in the Pleistocene, only one species in the genus *Equus* studied here had microwear consistent with pure grazing, although deeper time mesowear and hypsodonty proxies had values that are more consistent with grazing in extant forms. High degrees of microwear pitting and gouging were more accelerated from the early Miocene onward indicating exposure to exogenous grit on food items and most likely explaining the extreme acquisition of hypsodonty and blunter mesowear cusps in equids compared to other North American ungulate families. This acquisition of hypsodonty set the stage for the Equidae to become the only hypergrazer North American family in the Recent. Results here underscore the vital importance of utilizing more than one dietary proxy to provide enough information to reconstruct paleodiet with assuredness.

A New View: Multidimensional and Time Transgressive Approaches to Ecometrics

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Relationships between functional traits and environmental conditions are crucial for maintaining ecosystems through time, and ecometrics is a powerful approach for identifying those relationships. This approach analyzes the relationship between the functional traits of an entire community and the environmental conditions with which they are associated, serving as an alternative to taxon-based approaches that focus on individual species. For example, communities of herbivores with high crowned teeth (high hypsodonty) are likely to be found in arid areas with low precipitation because the high crowns facilitate ingestion of more grit and abrasive vegetation. Ecometrics enables us to test ecological and evolutionary processes that are responsible for the observed spatial distribution of traits. It can also be used to reconstruct paleoenvironments and assess the mismatch between expected and realized trait distributions within communities. Multiple ecometric relationships have been established for plants and animals but have not been thoroughly integrated across traits, taxonomic groups, or continents. New paleoclimate data and recent descriptions of new ecometric traits provide an opportunity to develop a more multidimensional and time transgressive approach. Here, we consider ways to expand these suites of ecometric traits and how to integrate a comprehensive set of traits into a multi-trait, multi-taxonomic framework. This integration serves as the next step in advancing our understanding of community-level relationships with the environment and thoroughly examining ecometric fit through time.

A review of the woolly rhinoceros Pleistocene record in Poland

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The woolly rhinoceros (*Coelodonta antiquitatis* Blumenbach 1799) was widely distributed across northern Eurasia, including Poland, during the Pleistocene. Polish evidence for this is provided in the form of over a hundred sites, which were however identified over sixty years ago (Kowalski, 1959), and some succeeding loose findings. We have thus no knowledge of the details of the woolly rhinoceros' presence; in particular, we do not know in geographical terms how widely it was distributed across Poland. Equally important as the distribution is the location of the sites which, as can be expected, will correspond to the position of the ice sheet in its several phases and the presence of the mammoth steppe, which was preferred by the woolly rhinoceros. We do not know either if its presence was permanent, temporary, or periodic. Further, none of the studies conducted so far have addressed the ancient DNA, which could shed light on ancient populations.

As the history of the woolly rhinoceros in Poland has not received sufficient attention, we will focus in this presentation on this key representative of megafauna, and one that is also well recognized in Europe.

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Building ecometric models using small mammal hypsodonty to estimate paleoprecipitation across East Africa

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By examining the relationships between fauna and climate through time, we can better anticipate how communities will respond to climatic changes. Ecometric analyses examine the relationships between functional traits and environment at the community level. Traits used in these studies directly influence how an organism interacts with its environment. Previous studies using ecometrics have explored relationships between hypsodonty (tooth crown height) and precipitation and temperature. Many studies in large mammals find that high hypsodonty is associated with low precipitation. However, recent work finds that hypsodonty in North American small mammal communities is also correlated with mean annual temperature with these communities showing more *in situ* changes in response to climate. Here, we examined community-level hypsodonty of African rodents and lagomorphs to test if the same relationship exists across geographic space. With projected warmer and drier climates, Africa's rich biodiversity is expected to see changes in community composition in the near future. To investigate this trait-environment relationship in Africa, categorical hypsodonty values (brachydont, mesodont, and hypsodont) were gathered from the literature and museum collections for 92 modern African taxa (86%). Equidistant 50-km points were used to generate community lists by sampling IUCN range maps. There was a stronger linear correlation between small mammal community-level hypsodonty and annual precipitation (r^2=0.61, p<.001) than mean annual temperature (r^2=0.05, p<.001) possibly due to less variation in temperature than precipitation across Africa. We use maximum-likelihood to construct ecometric spaces that predict paleoprecipitation for seven well-sampled Quaternary fossil localities from East Africa. We placed the fossil sites into our ecometric spaces based on their trait composition. One site had a non-analog community occupying trait space not represented by modern communities, meaning an estimate of precipitation is not possible using this model. Fossil communities had relatively lower mean tooth crown heights than most modern communities and, thus, often plotted on the wetter end of the range of trait space, suggesting higher precipitation during the Quaternary. For each site, small mammal hypsodonty ecometrics demonstrates how communities are shifting in trait space and in response to climatic change by revealing the direction and magnitude of change over time.

Interglacial or interstadial, difficulty in correlating local and global data during the middle Pleistocene at the Arago Cave.

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Middle Pleistocene is marked by the settlement of achelean and their diversification after the MIS 12. The Arago cave regroup numerous human settlements correlate to MIS 12, 13 and MIS 14 making it an important site for the comprehension of the Lower Paleolithic in Southwestern Europe. It's also an important site for the understanding of paleoenvironments and paleobiodiversity as it has yielded rich faunal associations. The faunal associations allow to observe three climatic stages within this recording: two cold ones and a mild one. The small vertebrates, with their abundance and their diversity, are particularly useful for the observation of these period, which historically have been correlated to glacial or interglacial stages. If the first cold phase, dated 438+/- 31ka is correlated to the Marine Isotopic Stage 12 (MIS 12), the correlation of the following phases to isotopic stages can be discussed. They may correspond to climatic variations of the MIS 12. Indeed, the latest studies about paleoclimatic reconstitution which allow to define the evolution of the paleo-temperature show that these differences are relatively small. Therefore, instead of a correlation to MIS 12, 13 and 14, the medium complex of the Caune de l'Arago could belong solely to MIS 12. The correlation of these environmental change to other global data, notably isotopic curve, is challenging because there are various local factors influencing faunal association. We propose here to present both hypotheses and to discuss the various factors which influence the distribution and the representation of the small vertebrate species present on the site.

Molluscs and Microfossils as indicators of early Holocene Palaeoenvironmental reconstruction of the Grand Erg Occidental, North-Western Algerian Sahara

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The witness hill in the sabkha El Mahouche of Grand Erg Occidental (North-Western, Algerian Sahara), revealed the existence of an Early to Mid-Holocene paleo-lake is located in the Northwestern Algeria Sahara 600 km away from the Mediterranean. The present study aimed to reconstruct the palaeoenvironmental changes of The outcrop, SMI (3.3 m) in length contained eight lithologic units, is almost completely composed of the mollusc shell five gasteropoda (Biomphalaria pfeifferi, Bulinus truncates, Hydrobia sp., Potamides conicus, Melanoides tuberculatus), and bivalve *Cerastoderma glaucum*, ten of fresh-brackish water ostracods, three benthic foraminifer species. The association indicates a fresh-brackish water lake with temporary inflows of freshwater, in order to reconstruct the palaeoenvironmental history of this outcrop. Which is subdivided into many ecological stages: The first stage consists of very shallow conditions, plant remains and rare freshwater ostracods indicate slightly brackish, and gastropods probably a swampy wetland which had established due to humid climate conditions. The second stage consists high abundance of fresh-brackish water ostracods and gastropods, and indicates a lake-level rise .The first development of a permanent water body points to a variable salinity, and therefore to unstable conditions of the lake's early phase.

The third stage includes gastropods (B. pfeifferi, B. truncates, Hydrobia sp.), and microfossil taxa communities are dominated by taxa tolerant in salinity conditions, followed by a relatively stable salinity level, which characterizes a fully established, relatively large water body. Indicates stable environmental conditions of a permanent fresh- saline lake.

The fourth stage begins while the prevailing ostracods Cyprideis torosa and Loxoconcha elliptica, together with the molluscs C. glaucum, Hydrobia sp., and P. conicus. The high number of foraminifers indicates an increase in salinity level point to a lake-level drop until the formation of gyps (last stage). About 7782 14C yr BP; the appearance of C. glaucum is evidence of the onset to aridification. As a consequence, the lake gradually begins to vanish.

Late Holocene mangrove dynamics of the Doce River delta, southeastern Brazil: Implications for the understanding of mangrove resilience to sea-level changes and channel dynamics

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This work aims to understand mangrove resilience to changes in a wave-influenced delta in southeastern Brazil during the late Holocene using an integrated analysis of palynology, sedimentology, and geochemistry ($\delta^{13}C$, $\delta^{15}N$, C:N and C:S ratio), and radiocarbon dating on two sediment cores. The data indicated three mangrove succession phases: 1) an estuarine point bar/tidal flat occupied by a mixture of mangrove species (~2660 - ~2050 cal yr BP); 2) a tidal flat dominated by *Laguncularia* mangroves (~2050 - ~900 cal yr BP); and 3) tidal flats with *Laguncularia* mangroves upstream and establishment of *Rhizophora/Avicennia* mangrove at the river mouth (~900 cal yr BP until present). The geochemical results suggest a dominance of C_3 terrestrial plants with a mixture of C_4 plants and organic matter of marine/estuarine origin throughout the late Holocene. *Laguncularia* and *Rhizophora* trees were established since ~2660 cal yr BP as pioneers, followed thereafter by *Avicennia*. Currently, tidal flats upstream are occupied by mangroves mainly represented by *Laguncularia*. *Rhizophora/Avicennia* mangroves occur at the mouth of the river. The relative sea-level fall during the late Holocene, as well as the channel dynamics, caused the development of tidal flats and mangrove succession inland. The succession of *Rhizophora*, *Laguncularia,* and *Avicennia*, followed by the permanence of only *Laguncularia*, is likely related to the resilience of each mangrove genus to habitat disturbance (e.g., salinity and sediment grain size fractions) caused by sea-level changes and channel dynamics. Our results show that mangroves may be resilient to the effects of Atlantic sea-level fluctuations, but the floristic structure in the past is different from that of today.

Complex vegetation response to glacial-interglacial cycles on the Loess Plateau of China over the past 800,000 years

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Reconstructing the paleo-vegetation on the Chinese Loess Plateau (CLP) is important to understanding the coupled relationship between vegetation and climate. However, the evolution of vegetation on the CLP during glacial and interglacial cycles of the Quaternary remains subject to controversy. Here we analyze $\delta^{13}C_{TOC}$, *n*-alkanes preserved in sediments from a 60-meter section, Lingtai, on the central CLP, as well as records of atmospheric temperature and monsoon precipitation based on the branched glycerol dialkyl glycerol tetraether (br-GDGT) membrane lipids and magnetic susceptibility (MS), to reconstruct vegetation and climatic factors over the last 800 ka. Based on increasing ratios of *n*-alkanes, a general increase in shrubland after 420 ka, with more grass generally in the past 250 ka is revealed. During the transition periods from glacial to interglacial, the appearance of $\delta^{13}C$ peaks, with values of >-21‰, along with higher ratios of $C_{31}/(C_{27}+C_{29}+C_{31})$ and $(C_{27}+C_{33})/(C_{29}+C_{33})$, indicate an increase in both C_4 grasses and C_3 shrubs. Depleted $\delta^{13}C$ values and lower $C_{31}/(C_{27}+C_{29}+C_{31})$ imply a greater contribution from C_3 trees during some interglacial periods, including in the lower paleosol layer of S5 (MIS13). During the transitions from late interglacial and early glacial, an increase in C_3 grasses is indicated by depleted $\delta^{13}C$ values and higher $C_{31}/(C_{27}+C_{29}+C_{31})$ ratios. In comparison with $\delta^{13}C$ records from the CLP along a SE-NW transect since the last glacial, the increase in C_4 plants is consistent with increasing temperature as indicated by br-GDGT proxies during the transition periods from glacial to interglacial, but occurs earlier than the intensified monsoon that is indicated by higher MS in paleosol layers. This implies that increasing abundance of C_4 plants is associated with the transitional periods from glacial to interglacial under conditions of higher temperature and drier climate in the central and southeast CLP. Lower $\delta^{13}C$ values (<-23‰) and lower $C_{33}/(C_{33}+C_{29})$ values (<0.3) correspond to periods of lower MAT and relatively depleted $\delta D_{wax,}$ implying that a moderately warm and wet climate is favorable to C_3 trees in this region. To conclude, rather than strictly following changes in monsoon intensity within a simple glacial-interglacial pattern, vegetation evolution on the CLP responds to complex hydrothermal dynamics.

Application of the Landscape Reconstruction Algorithm in the Northern French Alps to assess Holocene land cover changes

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Major trends in Holocene vegetation changes in the Alps are known based on palaeoecological studies. However, in the detail, disparities are observed both at regional and local scales. This is mainly due to the spatial variability of the mountain landscapes, e.g. different valleys and altitudes are characterized by different plant abundance/composition, resulting from a combination of factors such as soil characteristics, the natural distribution of plant taxa and local human activities. In the aim of assessing the spatial extent of past plant abundances and vegetation composition through time, there is still a critical need to disentangle the local from the regional vegetation changes.

Pollen-based vegetation modelling approaches have been developed to meet this challenge. However, such works are still few in mountain environments. In the present project, we aimed at reconstructing the spatial variability in regional and local plant abundances in a mountain region by applying the Landscape Reconstruction Algorithm (LRA) to reconstruct the spatial distribution of the vegetation in the Northern French Alps over the last 5 millennia.

Here, we present our methodological approach to calibrate models from modern vegetation and evaluate the performances of the LRA to assess both regional and local vegetation in a mountain region. 45 sites, including lakes and peat bogs were sampled in a region of 45 km^2 located between the Mont Blanc, the Lake Annecy and the Lake Geneva. Pollen and *seda*DNA analyses have been carried out on each top of these sediment cores. Current and historical regional vegetation maps are used to evaluate the performance of the REVEALS model (i.e. regional component of the LRA). Regarding the performance of the LOVE model (i.e. local component of the LRA), we use for the evaluation, the current vegetation units surrounding each site (within a 10km radius) based on vegetation maps and botanical surveys. The vegetation maps and the LRA runs are performed for specific time slice during the Holocene. This research aims at improving the use of the LRA to reconstruct past vegetation and land-use changes from a local to a regional scale in mountain regions, in general.

Age-mixing harmonizes apparent differences in extinction chronologies between fossil and eDNA records

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Environmental DNA (eDNA) collected from stratigraphic sections routinely identify megafauna DNA from sediments that are several thousand years younger than species' last fossil occurrences. While such records have been used to propose the survival of mammoths and other species well into the Middle Holocene, a unique challenge for using eDNA records to estimate extinction timing is that organisms can contribute DNA to sediments long after their deaths. eDNA archives mix undatable DNA from both living and dead individuals, thus the durations that bones and other biological tissues persist on landscapes impart important controls on the scale of temporal mixing within eDNA samples. To characterize how the duration of bone persistence changes due to environmental settings, we aggregated data from the literature on the oldest radiocarbon-dated surface-collected bones from different ecosystems. We included bones that we are reasonably confident persisted without being completely buried ("never buried"), and bones for which exhumation at some point cannot be confidently excluded ("potentially never buried"). We supplemented these data with AMS radiocarbon dated bones from Arctic Alaska and temperate North America. Pairing bone persistence with mean annual temperatures from their sample localities, we find a strong link between local temperature and the logged duration of bone persistence (never buried bones, $R^2 = 0.94$, $p < 0.01$; potentially never buried bones, $R^2 = 0.95$, $p < 0.01$). Using published data on Arctic mammoths as a test case, we find that the gap between the most recent fossil occurrence and the most recent sediments containing mammoth DNA (~7 kyr) is within expectations of the predicted duration of bone persistence for Siberian temperatures. Particularly in cold, high-latitude systems, decay rates of bones and other tissues are extremely slow and remains on landscape surfaces can be ubiquitous. Bones in these settings are frozen for much of the year and even highly weathered specimens, including those exhumed from permafrost millennia after initial burial, can release viable DNA. Rather than millennial-scale extensions to species survival, DNA from sediments that significantly postdate last fossil occurrences likely identify temporal mixing in eDNA and highlight commingling of the dead with the living.

Session 18:
Dansgaard-Oechger events in climate models and the real world

The regional imprints of Dansgaard-Oeschger events on land and marine environments

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One of the most important challenges of the IPCC is documenting the regional impact of the present-day global warming. Yet, identifying the regional expression of global changes is the first and necessary step to understand the mechanisms behind them. The best examples of past global warming events, comparable in velocity and magnitude to those expected in the 21st-century, are those associated with the Dansgaard–Oeschger (D–O) cycles that punctuated the last glacial period, ~115,000-27,000 years ago (115-27 ka). Reasonably well-chronologically constrained deep-sea and terrestrial records of D-O cycles provide an excellent opportunity for documenting the nature (shape, amplitude, timing and duration) of the vegetation, fire and oceanic regional responses to past rapid global warming events. Building on the ACER (https://doi.org/10.1594/PANGAEA.870867) and Paleo-Jump (https://www.tipes.dk/paleojump-a-tipes-database-for-research-on-rapid-climate-transitions/) databases, I will present a new compilation of D-O records from geochemical, sedimentological and micropaleontological data. I will pay particular attention to one of the best dated event, the D-O 8, centered at ~38,000 years ago (38 ka). It followed the Heinrich Stadial 4 cold phase (~40 -38 years ago), and occurred during a period of minima in precession and intermediate ice volume (Marine Isotope Stage 3). Compared to the other D-O events, D-O 8 was marked by strong Greenland warming, ~10°C, and strong increase in atmospheric CH_4 and CO_2 concentrations, by at around 150 ppb and 20 ppm, respectively, and was associated with a vigorous resumption of the Atlantic Meridional Overturning Circulation. D-O 8 warming has also the advantage to be relatively recent and, therefore, one of the best recorded all around the world.

The long and winding road to solving the enigma of DO-events

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The DO-events are the most profound expressions of rapid natural climate transitions observed in the Pleistocene climate record. They were first discovered in ice core records more than 30 years ago, but are only now in the infancy of being reproduced in climate models. This points to a complex sequence of events necessary for triggering the sudden warming and more gradual cooling events. These involving arctic sea blocking deep water formation, changing the Atlantic meridional overturning, influencing the transport of heat and salt etc. A lot of these processes are only partly known from the sparse paleoclimatic records. In order to guide the modelling, we shall focus on the high-resolution ice core record from Greenland and extract as much information as possible on the underlying dynamics from this one timeseries. By analysis the structure of the fast fluctuations in the record and the statistics of durations of DO-events we can make inferences on the causes and predictability of the transitions.

Modeling glacial climate variability with comprehensive Earth System Models – Advances and Challenges

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Rapid climate changes during the last glacial cycle are evident in marine and terrestrial records. However, as observations are spatially confined and differ in their temporal resolution and extent, the underlying processes triggering abrupt climate changes have not been fully understood. In order to improve the process understanding, a great advance has been made throughout the last years in developing and setting up comprehensive Earth System Models (ESMs) for simulating climate changes on glacial time scales.

The German paleo-climate modeling initiative PALMOD facilitated these efforts and allowed for the development of three ESMs with interactive ice sheets and solid Earth dynamics for the examination of climate changes and variability during different stages of the last glacial cycle, such as the last deglaciation and Marine Isotope Stage 3 (MIS3). Both periods exhibit abrupt climate events in observational records, such as Dansgaard-Oeschger (D-O) and/or Heinrich events (HEs).

A set of coordinated sensitivity experiments within PALMOD allowed to assess whether the ESMs are generally capable of simulating D-O events under realistic MIS3 boundary conditions. Comparing the independent ESMs and the boundary conditions necessary to trigger D-O like oscillations highlights the limitations of simulating abrupt events with comprehensive ESMs under realistic boundary conditions but helps to improve our understanding of the underlying mechanisms.

Anatomy of past abrupt warmings recorded in Greenland ice cores

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Several model-based mechanisms have been suggested to explain the abrupt climate variability evidenced in Northern Hemisphere paleoclimate reconstructions during the Last Glacial. However, because of the limited temporal resolution achievable in most climatic archives and relative dating uncertainties between paleoclimate records, it remains challenging to test the proposed processes with data allowing a subcentennial-scale investigation of the anatomy – the duration and temporal phasing – of the changes in different parts of the world.

Here, we overcome these limitations by using new and existing high/resolution records from the Greenland NGRIP and NEEM ice cores across the Last Glacial to map the pluriannual-scale evolution of tracers ($\delta^{18}O$, d-excess, Ca^{2+}, Na^{+}, annual layer thickness) which contain signatures of climatic changes in different regions of the Northern Hemisphere.

We highlight the absence of a systematic pattern in the anatomy of abrupt changes as recorded in different ice parameters. This diversity in the sequence of changes seen in ice-core data is also observed in climate parameters derived from numerical simulations which exhibit self-sustained abrupt variability arising from internal atmosphere-ice-ocean interactions. Our analysis of two ice cores shows that the diversity of abrupt warming transitions represents variability inherent to the climate system and not archive-specific noise. Our results hint that during these abrupt events, it may not be possible to infer statistically-robust leads and lags between the different components of the climate system because of their tight coupling.

A multiproxy record of Dansgaard-Oeschger events from 120 to 72 ka based on cave stalagmites from south-east France

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Dansgaard-Oeschger (D-O) events are one of the best examples of naturally occurring abrupt climate change. D-O events are clearly recorded in Greenland ice core records with coincident changes detected in marine and terrestrial palaeoclimate records spanning a range of climate zones. Cave stalagmites provide some of the best terrestrial records of D-O events as they preserve decadal resolution records, have multiple climate sensitive proxies, are widely distributed and, importantly, can be accurately and precisely dated by uranium-thorium dating. Cave stalagmites therefore offer the opportunity to improve our understanding of global climate tele-connections during D-O events and to improve the chronology of event timing. Here we present a stacked, multiproxy ($d^{18}O$, $d^{13}C$, Mg/Ca and Sr/Ca) stalagmite record providing near continuous coverage from 120 to 72 ka (MIS 5d-a). The stacked record is composed of four stalagmites from Saint-Marcel Cave and two stalagmites from Orgnac Cave. Both caves are in south-east France. Proxy variations are replicated well between temporally overlapping sections of the stalagmites. This provides confidence in the interpretation of the proxy variations as reflective of climate and environmental changes outside of the cave. Dating of each stalagmite is focused on the abrupt transitions to optimise the chronological determination of the timing of these events. A composite depth-age model is constructed based on the age measurements from individual stalagmites. The stacked record clearly records almost all D-O events spanning from Greenland Stadial 26 to Greenland Interstadial (GI) 19.2, demonstrating a strong sensitivity of rainfall and temperature changes at the site to climate changes in the North Atlantic region. In addition to recording the main D-O events, sub-millennial events, such as GI 23.2, GI 24.1b and GS 24.2, which are poorly studied outside of Greenland, are also recorded. This stacked record, based on six well dated stalagmites, provides improved understanding of the response to millennial and sub-millennial changes in western Europe, and refined chronological constraint for the timing of abrupt events throughout the early last glacial period.

Regionally coherent patterns of organic deposition in Japanese lakes track millennial scale variability in the East Asian Monsoon during Marine Isotope Stage 3

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The nature and timing of millennial scale variability across the East Asian Monsoon (EAM) during the last glacial cycle remains a point of debate, particularly in the maritime affected regions of eastern Asia. Here we infer regional scale hydroclimate variability between 50-10 thousand years before present (ka B.P.), based on three remarkably similar lake sediment total organic carbon (TOC) records, from Lake Suigetsu, Lake Nojiri and Lake Biwa, Japan. The three records were chronostratigraphically tied to the precise varve and radiocarbon chronology of Lake Suigetsu using common tephra layers, and by re-calibrating radiocarbon dates from Lakes Biwa and Nojiri using IntCal20 (and by extension, Lake Suigetsu) as the calibration reference. Based on this chronological alignment, TOC in the three cores correlates to a high degree ($R^2 > 0.6$), revealing a common, regional scale climate driver over environmental change on a centennial-millennial timescale.

Collectively, these records are interpreted to reflect regional scale hydroclimatic change, which is linked to variability in the EAM. Carbon isotope and C/N ratios from the Lake Suigetsu sediments indicate that variations in TOC are driven by changes in the flux of terrestrial organic matter to the lake. The Japanese lake TOC records exhibit marked similarities with speleothem, loess, marine and ice core records from across Asia, lending strength to the hypothesis of a linked winter and summer monsoonal cycle. In particular, several records highlight a period of markedly enhanced precipitation between 40-35 ka. There is no consistent correlation between millennial scale variability in Japan and Greenland ice core $d^{18}O$. However, a variable correlation exists between Japanese hydroclimate and Antarctic ice core $d^{18}O$, with a fluctuating sign and strength of correlation that appears to vary on an orbital timescale. We therefore support the hypothesis that a climate teleconnection with Southern Hemisphere and Pacific Ocean temperature had a major effect on precipitation in Japan during the last glacial period, possibly subject to modulation by the cross-equatorial insolation gradient.

Global patterns of climate change during Dansgaard-Oechger warming events in MIS3

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Quantitative information on climate changes during Dansgaard-Oeschger cycles is necessary if we are to understand better how these rapid events were expressed globally, how they impacted land ecosystems and biogeochemical cycles, and how well they are simulated by climate models. There are now many long terrestrial records covering the last glacial period, yet there has been no recent assessment of the implied climate signals. Only a few quantitative climate reconstructions have been attempted, and those available were derived using different methods. Here we use pollen samples from 73 sites globally, covering part or all of Marine Isotope Stage 3 (MIS3), to reconstruct changes in seasonal temperatures and moisture availability during Dansgaard-Oeschger warming events (D-O 12 through 5) using a partial least-squares calibration technique, based on the unimodal model of taxon abundances, that accounts both for sampling frequency (downweighting heavily sampled regions of climate space) and for the tolerance breadths (upweighting pollen taxa with narrow ranges) of the taxa in the (global) surface-sample training data set. We show large increases in both summer and winter temperatures in the northern extratropics, and these warmings are associated with significant changes in moisture availability. Seasonal warming is negligible in the tropical records, however, where changes in moisture availability dominate. Temperature changes in the southern extratropics were large, but in some cases anti-phased with those in the northern extratropics.

Matrix profile analysis of Dansgaard-Oeschger events in paleoclimate time series

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Dansgaard-Oeschger (DO) events are one of the most striking examples of abrupt transitions observed in paleoclimatic records, particularly from Greenland. The identification of DO events in an observational record, which has typically low resolution and significant high-frequency variability, cannot rely on visual identification alone, requiring robust non-subjective approaches. Of particular interest are data-driven methods that can be applied to diverse proxy records (ice cores, speleothems, marine and lake sediments), in a consistent and objective way.

In this study we apply a purely data-driven time series method, the Matrix Profile approach, which is an algorithmic approach depending only on the prescribed length of sub-sequences within a time series. The identification of similar patterns within a time series is based on the calculation of nearest neighbours between sub-sequences, estimated through z-normalized Euclidean distances. Here the Matrix Profile approach is applied in order to identify similar events within time series and also across multiple time series, using the NGRIP Greenland ice core and the CENOGRID marine proxy records. We show that the matrix profile approach is able to identify abrupt transitions and similarity in terms of shape patterns between events in an objective and consistent way.

Identifying the mechanisms of DO-scale oscillations in a GCM: A salt oscillator triggered by the Laurentide ice sheet

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The driver mechanisms of Dansgaard-Oeschger (DO) events remain uncertain, in part because many climate models do not show similar oscillatory behaviour. Here we present results from glacial simulations of the HadCM3B coupled atmosphere-ocean-vegetation model that show stochastic, quasi-periodical variability on a similar scale to the DO events. This variability is driven by variations in the strength of the Atlantic Meridional Overturning Circulation in response to North Atlantic salinity fluctuations. The mechanism represents a salt oscillator driven by the salinity gradient between the tropics and the Northern North Atlantic. Utilising a full set of model salinity diagnostics, we identify a complex ocean-atmosphere-sea-ice feedback mechanism that maintains this oscillator, driven by the interplay between surface freshwater fluxes (tropical P-E balance and sea-ice), advection, and convection. The key trigger is the extent of the Laurentide ice sheet, which alters atmospheric and ocean circulation patterns, highlighting the sensitivity of the climate system to land-ice extent. This, in addition to the background climate state, pushes the climate beyond a tipping point and into an oscillatory mode on a timescale comparable to the DO events.

An oscillating Atlantic Meridional Overturning Circulation during the last glacial period

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Abrupt climate changes over the last glacial period (~ 115 to 12 thousand years ago) are often associated with reorganisation of the Atlantic Meridional Overturning Circulation (AMOC). It has been suggested that the AMOC can exist in more than one stable mode, but the mechanisms leading to switches between different regimes are still not understood. It is also unclear how disruptions of the ocean circulation are connected to millennial-scale climate variability, such as Dansgaard-Oeschger events or abrupt transitions during the late last deglaciation.

Most attempts at theorising glacial millennial-scale variability have involved looking at heat and salt transfers between the subtropical and subpolar gyres. This is often referred to as the 'salt oscillator' mechanism, which in turn controlled the intensity of the North Atlantic current. We propose that the salt oscillator is in fact part of a larger motion combining harmonic and stochastic dynamics spanning through all components of the climate system when triggered by an initial excitation. Only under certain combinations of boundary conditions and forcings can multiple stable states coexist, sometimes leading to the activation of a pseudo-oscillating regime for thousands of years.

Based on a new set of last glacial maximum (~21 thousand years ago) simulations that oscillate when forced with snapshots of the early last deglaciation meltwater history, we propose a new way of visualising the stability of the AMOC and its shifts between different stable modes. We provide a detailed analysis of the heat and salinity tendencies in a comprehensive description of the different oscillating modes. Finally, we discuss how the freshwater forcing framework fits into the broader theory of glacial abrupt climate changes.

Effect of Climatic Precession on Dansgaard-Oeschger-Like Oscillations

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Using the climate model MIROC4m, we simulate self-sustained oscillations of millennial-scale periodicity in the climate and Atlantic meridional overturning circulation under glacial conditions. We show two cases of extreme climatic precession and examine the mechanism of these oscillations. When the climatic precession corresponds to strong (weak) boreal seasonality, the period of the oscillation is about 1,500 (3,000) years. During the stadial, hot (cool) summer conditions in the Northern Hemisphere contribute to thin (thick) sea ice, which covers the deep convection sites, triggering early (late) abrupt climate change. During the interstadial, as sea ice is thin (thick), cold deep-water forms and cools the subsurface quickly (slowly), which influences the stratification of the North Atlantic Ocean. We show that the oscillations are explained by the internal feedbacks of the atmosphere-sea ice-ocean system, especially subsurface ocean temperature change and salt advection feedback with a positive feedback between the subpolar gyre and deep convection.

Ocean-sea ice dynamics in the Nordic Seas across a stadial-interstadial transition – a modelling and data perspective

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We will present results of ABRUPT, a project in which we simulate and reconstruct the sea ice conditions, ocean hydrography and climate of the Nordic Seas, over two targeted Dansgaard-Oechger events. Multi-model output from three transient glacial GCM simulations (NorESM, CESM, MPI-ESM) and high-resolution reconstructions from an eastern Nordic Seas transect (from the Faeroe-Shetland Channel to the Fram Strait) show that ocean-atmosphere-sea ice processes and dynamics during the transition from H4 to GI8 are strongly coupled.
Both model results and reconstructions suggest subsurface ocean warming and polynya events in the southern- and northernmost Nordic Seas during the cold stadial. For a short time during the stadial to interstadial transition, a corridor of open water and hence sea ice-free conditions existed from the southern Nordic Seas all the way to the Fram Strait. The breakup of the sea ice cover is likely caused by the overshoot of AMOC during the transition and the associated enhanced ocean heat transport into the Nordic Seas. After the transition, winter sea ice grows back in the Fram Strait during the interstadial state, but the Southern Nordic Seas remain ice-free.

Climate feedbacks can be constrained by Dansgaard–Oeschger events

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There are large uncertainties in the estimation of the magnitude of biospheric feedbacks to climate: there are large differences between the estimates produced by Earth System Models and observations also have large ranges. The rapid warmings during the last glacial period, the Dansgaard–Oeschger (D-O) events, are comparable in both rate and magnitude to present-day warming and can provide a better constraint. We have successfully used these events to quantify greenhouse-gas climate feedbacks, using the global mean temperature change obtained from a climate model (LOVECLIM) simulation of D-O events and the radiative forcing brought about by greenhouse gases, calculated by their concentration changes in ice core records. We derive feedback estimates of 0.155 ± 0.035 W m^{-2} K^{-1} for CO_2, 0.114 ± 0.013 W m^{-2} K^{-1} for CH_4 and 0.106 ± 0.026 W m^{-2} K^{-1} for N_2O. These estimates are consistent but more tightly constrained than previous estimates.
This methodology can be applied to estimate other biospheric climate feedbacks, including land-surface albedo. Land-surface albedo can be predicted as a function of snow cover, vegetation height and maximum fAPAR (the fraction of Absorbed Photosynthetically Active Radiation). We reconstructed changes in vegetation height and maximum fAPAR using pollen data from individual sites covering the D-O events and derived snow cover changes from a climate model (LOVECLIM) simulation, then we applied a 3D variational technique to produce a global gridded map for each event from these site-based albedos. These values are then used to calculate the corresponding radiative forcing in order to estimate the land-surface albedo feedback in the same way as greenhouse-gas climate feedbacks.

Atmospheric CO2 impact on spontaneous Dansgaard–Oeschger type oscillations: oscillatory sweet-spot for three climate models

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1. *British Antarctic Survey*

Greenland ice core records feature Dansgaard–Oeschger (DO) events; abrupt warming episodes followed by a gradual cooling phase during mid-glacial periods. Here, we analysis spontaneous self-sustained D-O type oscillations reproduced in three climate models: CCSM4, MPI-ESM and HadCM3. The three models show D-O type oscillatory behaviour in a remarkably similar, narrow window of atmospheric CO2 concentrations between approximately 185 to 230 parts per million (ppm). This CO2 range also compares particularly well with Marine Isotopic Stage 3 (MIS 3 - between 27.8 – 59.4 thousand of years BP, hereafter ka) atmospheric CO2 values (233-187.5 ppm), when D-O events occurred with most regularity.

In all three models, the oscillatory experiments with higher CO2 show an increased built-up of stadial salinity in the upper ocean in the subtropics, especially in the eastern edge of the North Atlantic Current, compared with the ensemble mean: the tendency to re-invigorate the Atlantic Meridional Overturning Circulation (AMOC) is increased and so the system spend less time in the stadial phase. CO2 also affects North Atlantic and Arctic sea ice, determining interstadial and stadial duration. Similar sensitivity CO2 experiments performed with other climate models may help in further constraining the here-identified range of atmospheric CO2 (185-230 ppm) bounding this D-O sweet-spot.

Carbon fluxes during Dansgaard-Oeschger events as simulated by an Earth System Model. (Jochum, Chase, Nuterman, Pedro, Rasmussen, Vettoretti, Zheng)

Prof. Markus Jochum [1]

1. *TeamOcean*

The CESM with biogeochemistry is configured to simulate glacial climate. The integration shows transitions from interstadials to stadials and back. The amplitude of the associated Greenland and Antarctica temperature changes and the atmospheric CO2 signal are consistent with ice-core reconstructions, and so are the time lags between termination of a stadial, Antarctic temperature reversal, and the decline of the atmospheric CO2 concentration. The present model results stand out because the transitions occur spontaneously (without forcing changes like hosing) and because they reproduce the observed features above in a configuration that uses the same parameterizations as climate simulations for the present day (i.e., no retuning has been done). During stadials, precipitation shifts lead to reduced growth on land, which dominates the CO 2 increase; the ocean acts as a minor carbon sink during the stadials. After the end of the stadials, however, the sudden reversal of the stadial anomalies in temperature, wind, and precipitation turns the ocean into a carbon source, which accounts for the continued rise of CO2 for several hundred years into the interstadial. The simulations also provide a novel possible interpretation for the observed correlation between CO 2 and Antarctic temperature: rather than both being controlled by Southern Ocean processes, they are both controlled by the North Atlantic Ocean, and most of the extra CO 2 may not be of Southern Hemisphere origin. If the stadials are prolonged through North Atlantic hosing, the upper ocean comes to an equilibrium, and the CO 2 response is dominated by a single process: reduced export production in the North Atlantic as result of the collapsed overturning circulation. This is in contrast to the unforced simulation where the net ocean carbon flux anomaly is the sum of several regional responses of both signs and similar magnitudes. Reducing the aeolian iron deposition by half, to account for the observed reduction of Southern Hemisphere dust fluxes during stadials, reduces biological productivity and export production so that the Southern Ocean emerges as an important carbon source, at least for the three centuries up until a new equilibrium for the upper ocean is reached.

Session 19: Global characterization of the Neogene–Quaternary (Pliocene–Pleistocene) transition

Benthic δ18O and δ13C record from the Monte San Nicola section (Gelasian GSSP, Sicily)

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The Central Mediterranean region is traditionally acknowledged as a key reference area for investigating the global climate variability over the last few million years. In particular, the expanded open marine successions exposed along the coastline of Southern Italy and Sicily preserve a manifold array of paleoclimatic proxies, which can be tightly constrained in time by means of a detailed biomagnetostratigraphic framework (Cita et al. 2008; Capraro et al., 2017, 2022). In this context, the Monte San Nicola area (Southern Sicily) offers a spectacular stratigraphic succession that was employed for defining the GSSP of the Gelasian Stage (ca. 2.58 Ma; Rio et al., 1998). The section has been recently redefined as the basal Pleistocene Stage (Head et al., 2008), because the triplet of glacial episodes found immediately above the Gelasian GSSP (i.e., the MIS 100 - MIS 98 - MIS 96 glacials) is considered correlative to the definitive onset of the Northern Hemisphere Glaciation (NHG; Zachos et al. 2001). Recent studies on both the historical Monte San Nicola section, where the Gelasian GSSP is located, and adjacent profiles (Capraro et al., 2022) provided information on the long-term climatic evolution across the Gelasian and the MIS 100 glacial in particular (Becker et al., 2005). Nonetheless, documentation across the Piacenzian/Gelasian boundary is still sparse.

We are currently committed to reconstructing a continuous and chronologically sound benthic $\delta^{18}O$ and $\delta^{13}C$ record across the "Mandorlo" section of Capraro et al. (2022), with a specific focus on the interval straddling the Piacenzian/Gelasian boundary. Results achieved so far proved critical for pinning the Gauss-Matuyama geomagnetic reversal and establishing the relative positions of the main guiding criteria for recognizing the boundary, as well as new insights on the oceanographic and climatic evolution of the central Mediterranean at the beginning of the Northern Hemisphere Glaciation.

Paleomagnetic and oxygen isotopic analyses on a boring core drilled through the base of Quaternary from the marine sedimentary succession Chikura Group in the southern Boso Peninsula, Japan

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The Chikura Group is a Pliocene-Pleistocene marine sedimentary succession distributed in the southernmost part of the Boso Peninsula. This sedimentary succession is characterized by a strong and stable magnetic signal in addition to abundant marine microfossils. Due to this nature, the Chikura Group is suitable for paleomagnetic and paleoceanographic studies. To obtain a detailed paleomagnetic record of the Gauss-Matuyama geomagnetic reversal boundary, which is the stratigraphic guide to indicate the base of the Quaternary System, we conducted a drilling campaign to take an oriented-boring core (GM-1 core) through the base horizon of the Quaternary in the Chikura Group. As a result, we have successfully collected a core consisting of almost continuous sandstone-siltstone alternation over 51 m long. Oxygen isotope measurements of benthic foraminifera, done at every 1m stratigraphic interval, confirmed that the GM-1 core covers MIS (Marine Isotope Stages) 102-G1. At MIS 103, preliminary paleomagnetic measurements confirmed a VGP path across the equator with a paleointensity trough corresponding to the Gauss-Matsuyama boundary. We will discuss the geomagnetic field variation during the geomagnetic reversal by reconstructing a detailed paleomagnetic record around the G-M boundary and comparing them with the results of ^{10}Be measurements currently being conducted.

GELSTRAT: an international program reinvestigating the Neogene–Quaternary boundary at the type locality of Monte San Nicola, near Gela, Sicily

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The Global boundary Stratotype Section and Point (GSSP) at Monte San Nicola, near Gela, Sicily, Italy was proposed in 1996 to define the base of the Gelasian Stage, then the uppermost stage of the Pliocene Series, in recognition of the intensification of Northern Hemisphere glaciation. This GSSP acquired elevated significance upon its approval in 2009 to define also the base of the Quaternary System and redefine the base of the Pleistocene Series. It is placed at the base of the marly layer immediately overlying the prominent, laminated, reddish, sapropelic Nicola bed, and has an astronomically tuned age of 2.58 Ma. The Nicola bed is assigned to Mediterranean Precession-Related Cycle 250 and aligns with an obliquity maximum representing Marine Isotope Stage 103 which, together with the Gauss–Matuyama paleomagnetic reversal, facilitates global correlation. Fine details of the stratigraphy nonetheless remain uncertain, including the precise position of the Gauss–Matuyama relative to the GSSP. GELSTRAT was inaugurated in September 2021 during an INQUA-SQS International Field Workshop focused on the reinvestigation and reanalysis of the Gelasian GSSP using modern methods and a broad range of proxies. Sampling across the boundary interval at the type section in September 2021 was supplemented by further fieldwork in April–May 2023 and resulted in the collection of 404 samples across a ~18 m stratigraphic interval spanning the GSSP and ranging from the top of bed A1 to ~10 m above the top of the Nicola bed (A5). Samples were collected at ~5 cm intervals. Pervasive fine-scale tectonic fracturing of the Monte San Nicola outcrop, coupled with the brittle nature of the dominant marl lithology, makes closer-interval sampling challenging although several narrow blocks of the finely laminated Nicola bed were collected for additional microstratigraphic analysis. GELSTRAT is an international collaborative program in which approaches planned or in progress include: calcareous nannofossils, foraminifers, pollen, dinoflagellate cysts, macrofossils, ichnofossils, foraminiferal stable isotopes, organic geochemistry, clay mineralogy, magnetostratigraphy, and ^{10}Be analysis. A refined characterization of the Gelasian GSSP will enhance its utility for the precise recognition of the base of the Quaternary on a global scale.

Paleoclimate evidences from calcareous plankton assemblages at the Pliocene-Pleistocene transition (Monte San Nicola section, Sicily)

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The present work is part of the GELSTRAT project, inaugurated in September 2021 during an INQUA-SQS International Field Workshop and focused on a high-resolution investigation of the Pliocene-Pleistocene transition (PPt), in the marly succession of Monte San Nicola - MSN (Gela, Sicily). The section represents a chronostratigraphic reference, as it contains the Global Stratotype Section and Point (GSSP) of Gelasian (ca. 2.58 Ma), the chronostratigraphic boundary that actually marks the base of the Quaternary System. Within the GELSTRAT project, the MSN succession was sampled in great detail, providing a temporal resolution of one sample every ~ 1 ka, from the top of sapropel A1 to ~10 m above the top of sapropel A5 (Nicola bed). The study interval is placed at the transition between the end of a relatively warm climatic phase, the so-called Pliocene Warm Period, around the 3 Ma, and the progressive intensification of the North Hemisphere Glaciation (NHG). It includes MIS 100, considered as one of the first pronounced glacial stage at the onset of NHG. Recent studies have been performed on the same section or on complementary outcrops, mainly focusing on the long-term stratigraphic features of the whole stratotype section or detailed isotopic studies on specific interval such as MIS 100 revealing climate evidences very similar to those observed during the Late Pleistocene Dansgaard–Oeschger and Heinrich events. However, more extended high-resolution studies on paleoclimate signal, as recorded by calcareous plankton across the transition, are still very scarce. The present contribution provides preliminary high-resolution quantitative results on calcareous nannofossil and planktonic foraminifera assemblages revealing significative glacial-interglacial and higher frequency paleoenvironmental changes, which improve the recognition and interpretation of climate variability across the PPt.

Assessing vegetation change and climate variability across the onset of Northern Hemisphere glaciation in the central Mediterranean area: The Monte San Nicola section

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In the frame of the international program GELSTRAT, devoted to revisiting and documenting the Gelasian GSSP at high temporal resolution, using a multi-proxy approach (sedimentology, magnetostratigraphy, beryllium-10, marine and terrestrial biostratigraphy and paleoecology, geochemistry), pollen investigations are in progress on the samples collected at the type locality of Monte San Nicola (near Gela, Sicily). Here, across the ~18 m stratigraphic interval, including the GSSP, from the top of bed A1 to ~10 m above the top of the Nicola bed (A5), 440 samples were collected in marls and sapropels. Pollen samples were processed at the palynological laboratory of the university of Florence. Many of them, especially from the base up to the top of A4, exhibit low to very low pollen concentrations. However higher concentrations characterized the interval at the Piacenzian/Gelasian transition. The high-resolution pollen analysis documents cyclic behavior of flora and vegetation at the beginning of the Northern Hemisphere glaciations. Subtropical humid forest taxa are overall scanty with the exception of *Cathaya*. On the other hand, deciduous temperate forest (especially deciduous *Quercus*), altitudinal coniferous forest (*Picea* and *Abies*) as well as open, herbaceous vegetation are quite well expanded documenting temperature and humidity changes, during the successive glacial/interglacial cycles. Current state analysis shows that open vegetation and especially steppe taxa (e.g., Amaranthaceae, *Artemisia*, *Ephedra*) exhibit an increasing trend, which becomes more evident above A5. Dry conditions seem especially expanded after 2.58 Ma; on the other hand, just before, humid and cold phases are frequent as attested by the increase of montane coniferous taxa (especially *Picea*), e.g. in the sapropel A4/5 (MIS 104).

The flora composition, vegetation structure, and the glacial/interglacial patterns at Monte San Nicola (southern Sicily) are compared with those from the coeval pollen records from several Mediterranean sites according to E-W and N-S transects. This also contribute to a better depiction of the Gelasian GSSP, enhancing its utility for global correlation as well as to an accurate detection of the base of the Quaternary on a global scale.

Session 20: Subglacial erosion, transport, and deposition: from landform and sediment evidence to modeling

Quantifying Subglacial Processes associated with soft bedded glaciers

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Understanding subglacial processes are vital in predicting modern sea level rise as well as reconstructing the formation of subglacial tills. We examine a series of modern soft-bedded glaciers in maritime locations and use a range of techniques (including *in situ* Glacsweb probes and web-connected GPS systems) to examine their subglacial seasonal behaviour, during summer and winter. We investigate different subglacial hydrological patterns. We are able estimate the relatively sliding and deformation associated with different subglacial water pathways and relate this to till deposition.

Glacial erosion: controls and global distribution

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Glacial erosion has often been parameterized as proportional to glacier sliding velocity, while the role played by local geology, hydrology and climate remain largely unquantified. As a result, our understanding of the links between global climate, tectonics and glacial erosion is limited. To address this shortcoming, we present a comprehensive synthesis of previously published Quaternary glacial erosion rates from six different measurement techniques integrated over 10^{-2} to 10^{6} years: (i) instrumental measurements beneath active glaciers, (ii) sediment fluxes derived from meltwater streams or (iii) ice-marginal deposits, (iv) terrestrial cosmogenic nuclide dating (TCN), (v) luminescence thermochronometry, and (vi) relief generation of chronologically constrained surfaces. Our synthesis includes 1065 empirical data points and 465 erosion rates from ice sheets, ice caps, and topographically confined glaciers that range over six orders of magnitude, between 10^{-4} and 100 mm yr^{-1}. Using a filtered dataset of contemporary erosion rates, we apply machine learning tools, using available environmental, glaciological, and geological datasets to assess the dominant controls on subgroups of nominal data categories. On a global scale, while glacial sliding velocity is an important control, we also discover equally strong or stronger correlations between other glaciological, environmental, and lithological parameters and glacial erosion rate, some of which have not been previously documented.

Discriminating substrate geology and ice flow velocity controls on subglacial streamlined landforms and surfaces under a paleo ice stream in central Canada

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The Peterborough Drumlin Field (PDF: 5000 km^2) in Southern Ontario, Central Canada contains some 3000 streamlined bedforms. LiDAR mapping and statistical analyses show continuums between drumlins, grooved drumlins, and megascale glacial lineations, that previous work showed to be erosional in origin, cut below a soft-bedded terrestrial paleo ice stream flowing off the Algonquin Highlands south to the interlobate Oak Ridges Moraine during the final stages of the last glaciation c. 12000 years before present. Using the curvature-based relief separation method for mapping the morphology of these bedforms we identified eight morphotypes and in addition, six types of streamlined surfaces characterized by specific assemblages of morphotypes recording a progressive reduction of bed relief and roughness by subglacial erosion. Initial statistical analysis shows that more elongated morphotypes and streamlined surfaces are grouped into distinct flow sets suggesting the primary importance of variation in flow velocity across the ice stream in shaping and smoothing the bed. This study tests this hypothesis by exploring the specific role of substrate geology in bedform evolution established by observations and facies analysis of sediments exposed in numerous road cuts and quarries. This exercise confirms previous suggestions that bedform geology is unchanging and consists largely of an older till (Northern Till) deposited during the Last Glacial Maximum of the Laurentide Ice Sheet which was subsequently eroded by faster flowing streaming ice during deglaciation leaving a thin upper till cap. Confirmation of the primacy of ice flow velocity in controlling morphotypes and surfaces now allows glaciodynamic modeling and recognition of specific ice flow velocities from streamlined morphotypes and surfaces on ancient ice stream beds.

LiDAR mapping of drumlinoids formed by erosion below a deforming subglacial erodent layer at Saskatchewan Glacier, Canadian Rocky Mountains

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Saskatchewan Glacier is the longest (12 km) outlet glacier of the Columbia Icefields in the Canadian Rocky Mountains of Alberta, Canada and attained its maximum Little Ice Age (LIA) extent in 1853. Unusually, for valley glaciers in the region which flow for the most part over hard rock beds, the retreat of Saskatchewan Glacier is exposing an extensive (10 km^2) till bed with numerous low relief drumlinoids revealed by high resolution (+10, 000 pts/m^2) LiDAR mapping. These are cored by antecedent sediment (glaciofluvial outwash, glaciolacustrine silt, and valley side alluvial fan debris) draped erosively by a thin (< 1 m) clast-rich LIA till. Drumlinoid surfaces have been extensively striated by individual clasts and clast clusters being swept across underlying sediments within a clast-rich subglacial traction carpet (erodent layer) now preserved as a thin (< 1 m) 'traction till.' Drumlinoid surfaces closely resemble slickensided fault planes. Larger boulders being driven across drumlinoids d left plough marks in their wakes and crescentic ramps of thickened till wrapped around their leading edges. Subglacial debris was driven to the ice margin and swept forward during winter and episodic multi-year still stands, into hummocky push moraines. Soft till was also squeezed into irregular ridges at the base of crevasses, and molded in the lee of large, lodged boulders into longer flutes that propagated in length downglacier. LiDAR and outcrop data confirm that drumlinoids are the product of erosional streamlining of overridden sediment by a deforming subglacial clast-rich 'erodent layer' between ice and its bed. The same fundamental erosional stratigraphy, where a thin till cap truncates older streamlined sediments occurs widely below the beds of other retreating LIA glaciers indicating the global relevance of the erodent layer model. The work reported here underscores the need to expand high resolution LIDAR mapping of Little Ice Age and Pleistocene glacier beds.

Murtoos and subglacial meltwater dynamics: examples from the Fennoscandian Ice Sheet area

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The present paper summarizes the main characteristics of murtoos found from the Fennoscandian Ice Sheet area with remote sensing and numerous murtoo excavations in Finland and Sweden. By using examples of their spatial and temporal relationships with other glacial landforms, subglacial meltwater routes and lithofacies analyses, we describe three main observations. First, murtoos are formed subglacially, which is seen from their orientation parallel to ice flow and associations with eskers and subglacial meltwater routes. For example, murtoos are sometimes overlain by eskers, glacial lineations and De Geer moraine ridges. Some murtoos are also covered by loose diamicton (flow till) that was deposited in the final phase of deglaciation. Second, the morphometric diversity of murtoos and murtoo-related landforms in the Fennoscandian Ice Sheet area is significant, with triangle-type murtoos the most representative and distinctive examples of murtoo landforms. Thie murtoo continuum describes the complexity of subglacial processes, including changes in ice flow velocity, water pressure and ice-sediment coupling, during deglaciation. Third, murtoos are depositional landforms composed of silt/clay-poor, sandy and gravelly diamictons interbedded with sorted glaciofluvial sediments. We provide a general structure of murtoos and typical sediment lithofacies found in murtoos and murtoo-related landforms. We suggest murtoo sediments are produced by pulsed, highly sediment concentrated flows during deglaciation concurrent only weak glaciotectonic deformation. Importantly, murtoos potentially represent a transition form from non-channelized to channelized subglacial drainage networks, which is important from the viewpoint of glacial hydrology and ice-sheet dynamics. Murtoos may thus provide new information for glacial modelling approaches by introducing the missing link between inefficient and efficient subglacial drainage, and thereby also increase our understanding on how current glaciers will behave in the warming climate.

A model of ice-marginal sediment-landform development at Lake Tekapo, Southern Alps, New Zealand

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1. *Leeds Beckett University,* ***2.*** *Durham University,* ***3.*** *University of Leeds,* ***4.*** *University of Canterbury*

The extent of the Southern Alps icefield in New Zealand is well-constrained chronologically for the last glacial cycle. The sediment-landform imprint of this glacial system, however, offers insight into ice-marginal processes that chronological control cannot. We present the first detailed investigation of sediments along the south-western shores of Lake Tekapo, South Island. We identify seven lithofacies, from which a five-stage palaeo-glaciological reconstruction of depositional glaciotectonic events is proposed: (i) ice-marginal advance and deposition of outwash gravels in lithofacies (LF) 1; (ii) ice-marginal recession and the development of an ice-contact lake, manifest in rhythmite deposition and iceberg rafting of dropstones (LF 2), followed by a depositional hiatus; (iii) ice-marginal recession recorded in ice-proximal aggradation of glaciofluvial hyperconcentrated flows (LFs 3, 4); (iv) ice-marginal advance documented by glaciotectonic disturbance and localized hydrofracturing, coeval with the deposition of delta foresets and a subglacial diamicton/till (LFs 5, 6); (v) final stages of ice-marginal recession and deposition of outwash gravels in LF 7. Two infrared stimulated luminescence ages were obtained from the glaciolacustrine sediments and, whilst the dating has some limitations, the sediments pre-date both the global and local Last Glacial Maximum. This reveals that the sediments do not relate to the age of the landforms stratigraphically above them and suggests perhaps that more recent glacial advances lacked capacity to erode the underlying pre-existing sediments deposited during the penultimate cycle, thereby reducing the accommodation space in the valley overdeepening. Overall, this outcrop records phases of valley aggradation throughout multiple glacial cycles which is preserved in substantial volumes. Such findings are not new features of the Quaternary stratigraphy in New Zealand; extensive *in-situ* sediments that have survived subsequent ice re-advances are consistent with sediment fills recorded elsewhere across South Island.

Genesis of glaciofluvial hummocks in subglacial meltwater corridors of the Slave Geological Province, Canada.

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The Slave Geological Province in Northern Canada was affected by the Laurentide Ice Sheet during the last glaciation. A distinctive record of this is a network of 'subglacial meltwater corridors' (SMCs), consisting of relatively continuous, narrow, sub-linear tracts where till has been eroded, bedrock is commonly exposed, and glaciofluvial landforms were deposited. SMCs are parallel to sub-parallel with deglacial ice flow directions and have undulating longitudinal profiles. Till dominates in intervening areas. Here we discuss the origin of SMC's and genesis of the landforms within them.

Eskers make up a small proportion of the glaciofluvial features in most SMCs, more common are scour zones and variably shaped depositional landforms referred to as 'hummocks,' composed of sandy diamicton. Hummocks typically occur in groups of tens but can number in the hundreds. Features range from individual mounds to irregular complexes with multiple high points. Sample transects from unmodified till into the SMC's indicate the hummocks are much sandier than the regional till. In some SMCs, the hummocks are streamlined. Limited morphometric analysis shows that individual features have a mean length-to-width ratio of 1.8. The average mound elongation direction usually parallels the final ice flow that affected the area.

These results and mapping relationships suggest the corridors were formed from subglacial meltwater flow. SMCs likely formed late during deglaciation because in most areas, the hummocks and eskers that they contain do not appear significantly affected by ice flow. In SMCs that contain both eskers and hummocks, depositional relationships indicate esker ridges were deposited after the glaciofluvial hummocks. We hypothesize that transient, sheet-type subglacial meltwater flow events resulted in erosion and transport of till to form the SMC's. Glaciofluvial hummocks formed from the rapid deposition of eroded till while eskers likely formed further downflow during the waning stages of these flow events. SMC's and related landforms likely formed in short segments in a time transgressive manner. Meltwater could have been sourced from supraglacial lakes that drained in catastrophic pulses. It is possible that SMCs are the Quaternary landscape record of lake-drainage events similar to those that occur presently in Southwest Greenland.

Session 21: Records of climate change from MIS 3 and MIS 2 in the Southern Hemisphere: The Lynda Petherick Memorial Session

The Last Glacial Maximum on Minjerribah – North Stradbroke Island: Lynda Petherick's contribution to understanding of Australia's late Quaternary environments.

Prof. Patrick Moss [1]***, Prof. Hamish McGowan*** [2]

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Lynda Petherick's research on the last glacial environments of Minjerribah (North Stradbroke Island), Southeast Queensland, Australia provided important impetus in developing the island as a crucial location for understanding eastern Australian Sub-Tropical Quaternary environments, particularly in a global context. Lynda focussed on two sites, Native Companion Lagoon and Tortoise Lagoon, with an emphasis on analysis on dust to examine climate dynamics during the Last Glacial Maximum (LGM), as well as pollen and charcoal analysis to understand landscape processes. This presentation will provide an overview of this research, as well as examining new research that has built on the significant foundations that Lynda's research has provided. In particular, a focus will be on landscape change over the last 45,000 years for the southeast coastal dunes of Minjerribah. This region has evidence of continuous human occupation from beyond the LGM to present, and the Native Companion Lagoon site provides important insight into the regional landscape change for this locality. Furthermore, a new LGM site, Jumping Grass Marsh, situated near the settlement of Dunwich will be discussed. This site provides new information on LGM environments through pollen and charcoal analysis that can be related to both Native Companion and Tortoise Lagoons and builds on the previous work undertaken by Lynda on LGM environments for sub-tropical eastern Australia.

A glacial chronology from sub-Antarctic Marion Island for MIS 3 and MIS 2

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It is increasingly apparent that local and regional factors, including geographic location, topography, and climatic variability, strongly influence the timing and extent of glaciation across the Southern Hemisphere. Glacial chronologies of sub-Antarctic Islands can provide valuable insights into the nature of regional climatic variability and the localised response(s) of glacial systems during periods of climatic change. On Marion Island, southern Indian Ocean, new cosmogenic 36Cl exposure ages confirm a local Last Glacial Maximum was reached prior to ~35 ka. Ice retreated throughout MIS 2 with minor standstill events between ~33-26 and ~20-17 ka, with limited evidence of ice re-advances during the Antarctic Cold Reversal or Holocene cooling periods. In this talk we compare Marion Island's glacial chronology with other sub-Antarctic islands (e.g. the Kerguelen archipelago, Auckland and Campbell islands, and South Georgia) and continental mountain glaciers (e.g. Patagonia and New Zealand) and review the evidence for a Southern Hemisphere glacial maximum in late MIS 3 (~41 ka), and glacier responses to cooling periods around ~32 and 21 ka. At a regional scale, sea surface temperatures and the position of the Southern Westerly Wind belt are recognized as key controls on ice accumulation due to their influence on air-temperature and precipitation regimes and the equilibrium-line altitude. At a local island scale, geomorphological mapping shows that deglaciation of individual glacier lobes was a-synchronous due to local physiography and topographical factors controlling the island's micro-climate.

Wood charcoal from Knysna Eastern Heads Cave 1: Evidence for the impact of the Last Glacial Maximum climate on woody vegetation and people of the Palaeo-Agulhas Plain, southern Africa

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The Last Glacial Maximum (LGM) is important for understanding the change from the Middle Stone Age (MSA) to Later Stone Age (LSA) in southern Africa. Evidence for this transition is often found in archaeological sites from the interior of the subcontinent. However, coastal sites hold unique evidence for the effects of glacial MIS 2 climates on the coastal landscapes and the resources on which people depended. The Knysna Eastern Heads Cave 1 (KEH-1), situated on the coastal margin of the southern Cape, is one of very few sites which preserve the continuity of life in the southern Cape across the MSA and LSA. It is currently being investigated to better understand the effects of the 26- thousand years old (ka) orbital forcing on southern Africa's coastal ecosystems. The glacial conditions of the LGM prompted an approximately 120 meters of sea level drop which opened more than 80 km2 of coastal plain, the Palaeo-Agulhas Plain (PAP), in the southern Cape of South Africa. This now-extinct landscape expanded the Cape Floristic Region (CFR) of South Africa and diversified the resource base for the human populations during MIS 2. KEH-1 accommodated some of these human populations who first invented the LSA lithic tool industry. Their adaptation to the LGM environment is partially visible in the archaeological and palaeoenvironmental record of the cave. Here, we present the preliminary results for the analysis of wood charcoal from three stratigraphic units (Dark Brown Spally, Dark Shelly and Dense Hearth Aggregate) of KEH-1 that are dated between >45 and 22 ka. This charcoal assemblage represents the subset of woody vegetation which grew in the vicinity of the site including parts of the PAP. We use the occurrence and diversity of the vegetation communities represented by this charcoal, to discuss the climate and its significance to the wider southern Cape ecosystem. We also use this vegetation subset to reconstruct the pattern of KEH-1 occupation by people and contextualise their foraging strategies spanning the MIS 3- 2 period.

Sedimentology and Luminescence Chronology of Glaciation in the Upper Clutha River Drainages, South Island, New Zealand

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Southern Hemisphere glaciation bears similarities and contrasts with its Northern Hemisphere counterparts. In New Zealand, the last glaciation featured early maxima that shifted northward through MIS 3-2 (60-15 ka). The upper Clutha River region fills a spatial gap in data from the South Island, revealing five glacial advances.
Sediments document three advances during MIS 3. The earliest occurred ca. 60 ka, as reflected in distal outwash at Beacon Point on Lake Wanaka. Distal outwash at Beacon Point and 7 km downvalley at the Cardrona River indicate extensive ice ca. 42 ka. A third advance ca. 32 ka is well-documented through rapidly aggraded outwash gravel at Beacon Point and deformed ice-terminal diamicton and gravel in a moraine at Kirimoko Crescent.
Two additional ice advances mark MIS 2. At Glendhu Bay, a terminal ice lobe deposited proglacial gravels, deformed by ice overrun, and delta foresets, dated to 29 and 28 ka, respectively. Correlative 29 ka sandy lacustrine strata at Deans Bank, near the Lake Wanaka outlet, also document the advance. The youngest advance is documented in extensive exposures at Lake Hawea, 12 km NE. Basal outwash dates to 20-19 ka, overlain by diamicton and lake sediments suggesting that the terminal moraine impounded the drainage, with lake floor gravel-sand deposits documenting subglacial lacustrine water discharge. Downstream, correlative outwash at Reko's Point Conservation Area on the Clutha River dates to 22 ka. The youngest dated glacigenic deposits are two outwash units dated to 18 and 17 ka at Deans Bank.
MIS 3-2 glaciation in the Clutha shows similar advance timing as other regional records. The ca. 40 and 32 ka advances correlate closely with advances in the Rangitata Valley, and the 32 ka advance correlates with CRN-dated advances at Lake Ohau and elsewhere. The 60 ka advance is indistinguishable from 65 ka advances at Lake Pukaki and the Rangitata Valley, together documenting an early glacial maximum in the southern half of the South Island. Cumulatively these results demonstrate that ice extended to or beyond ”LGM limits during several intervals in MIS 3 and early MIS 2.

Glacial to millennial variability in the Southern Hemisphere westerlies

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The Southern Hemisphere westerly winds (SHWW) play an important role in the global climate system through interhemispheric ocean and atmospheric linkages. It has been proposed that changes in the position of the westerlies on millennial to orbital timescales, may have an influence on Southern Ocean carbon storage, thereby acting as a critical feedback mechanism for driving changes in atmospheric CO_2 and global climate. However, climate model simulations and proxy records of past changes in the position of the southern westerlies provide an inconsistent view of SHWW behavior. Here, we use measurements of leaf wax hydrogen isotopes and the MBT'_{5me} paleotemperature index to reconstruct climate variability in the southern mid-latitudes over the past 50 k from a maar lake system on the North Island of New Zealand. We interpret leaf wax hydrogen isotope variability as reflecting changes in the position of the SHWW – an interpretation that is grounded in the analysis of modern precipitation isotopes. Our results indicate that the SHWW shifted in phase with the ITCZ on a range of timescales (e.g., orbital to millennial, including during the during the Holocene) throughout the record, and reflect the dominant role of interhemispheric temperature gradients in driving global atmospheric circulation response to climate forcing. Conversely, temperature changes reflect a southern high latitude signal, with orbital to millennial-scale variability synchronous with reconstructions from Antarctic ice cores. These results show that millennial-scale warming (i.e., during AIM events) was not restricted to the high-latitudes but reached at least as far equatorward as the Southern Hemisphere subtropics. However, despite the SH polar signal dominance on temperature, our reconstructions show that precipitation and SHWW behavior was controlled by changes in the Northern Hemisphere high latitudes.

Southern Ocean mechanisms of CO2 draw down and release on glacial-interglacial timescales

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The Southern Ocean is a major regulator of global climate, connecting the world's ocean basins as well as the atmosphere and deep ocean through both lateral and vertical exchanges of heat and carbon. Despite the importance of this region to global climate, however, its response to future climate change remains uncertain. Studying how the Southern Ocean operated under past climate states offers an opportunity to better understand the processes governing its role in climate today. For example, the Southern Ocean is widely believed to have played a driving role in the atmospheric CO_2 swings of the ice ages, ventilating carbon-rich deep waters to the atmosphere during interglacial periods and facilitating abyssal ocean carbon storage (by limiting this deep-surface exchange) during glacial periods. However, direct evidence of this abyssal carbon storage during glacial times – and the processes responsible for it – remains limited.

Here we present a suite of geochemical proxy records providing new insights into Southern Ocean circulation and carbon cycling, documenting abyssal ocean carbon storage as a mechanism of atmospheric CO_2 draw down over the Last Glacial Cycle. Trace element and stable isotope ($d^{13}C$, $d^{18}O$, $d^{11}B$) compositions of benthic foraminiferal calcite from the Indian Ocean sector of the Southern Ocean show how carbon was sequestered in the deep ocean over the course of glaciation and subsequently released to surface waters during deglaciation. These dynamics are captured by geochemical records reflecting temperature, pH, productivity, and circulation changes in the Southern Ocean over the Last Glacial Cycle, providing crucial insights to the processes responsible for this carbon cycling. Comparison to Earth system model output provides further context for the dynamics evinced by the proxy data. These results together form a more comprehensive picture of Southern Ocean carbon cycling over the Last Glacial Cycle and provide a foundation from which to develop a better mechanistic understanding of the Southern Ocean's role in past and future climate change, including processes such as advection and mixing, ocean-ice interactions, and productivity and nutrient dynamics.

Monsoonal variations during MIS 3 and 2 in the Kimberley, north-western Australia

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The climate of the Kimberley region in north-western Australia is characterised by the Indo-Australian Summer Monsoon (IASM). Variations in the strength and position of the monsoon are caused by its interaction with other regional climate drivers and have significant control on the vegetation of the region. Since the arrival of humans to Sahul, large-scale climatic variability in response to Heinrich and Dansgaard–Oeshger events and the Last Glacial Maximum have influenced tropical Australia. There are several intervals during Marine Isotope Stages 3 and 2 during which the response of the IASM to these global events is unclear or debated, owing partly to the scarcity of records extending through the late Quaternary from northwest Australia.

We present pollen, charcoal and geochemical records from the eastern Kimberley extending around 72 ka, beyond the first known arrival of humans to the continent around 60 ka ago. A sediment core collected from the northern edge of the Tanami Desert in a low-relief, seasonally inundated floodplain is consistent with regular sedimentation, and captures an environmental signal from the present-day southern edge of monsoonal influence. To the north, 60 km south of the Joseph Bonaparte Gulf, a second core was collected in the back plain of the Bullo River, well within the zone of monsoonal influence. The cores' collective results permit interpretation of variations in both the strength and latitudinal migration of the IASM.

The results of this research show variations in the regional environment of both locations, although the southern core appears to reflect more stable conditions. Geochemical and pollen results indicate intervals of stronger and weaker monsoon activity, which span timeframes where either few studies exist, or there is debate surrounding the interpreted environmental conditions.

Session 22: Mountain glaciations and their diversity: Perspectives in geomorphology, geochronology, palaeoglaciology, and palaeoclimatology

Glaciers and ice caps under climate change since the Little Ice Age

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Mountain glaciers and ice caps are undergoing rapid mass loss but rates of contemporary change lack long-term (centennial-scale) context. Future projections of glacier changes require spin up to present day conditions and thus baseline ice extents and ice volumes are a prerequisite for model validation. Here, we review reconstructions of the Little Ice Age maximum glacier extent and ice surface of glacier around the World.

We focus on Jostedalsbreen, which is the largest ice mass in mainland Europe, but make comparison with our other published analyses of changes to mountain glaciers and ice caps since the LIA to show that Jostedalsbreen is unusual in not exhibiting an acceleration in mass loss since the LIA. Indeed, we have reported a 23 % acceleration of glacier mass loss in NE Greenland and a doubling for the Southern Alps of New Zealand. Others have reported a doubling of the rate of mass loss for the Vatnajökull ice cap and for Patagonia since the LIA. We have recently reported a ten-fold increase in glacier mass loss for ~ 15,000 glaciers across the Himalaya. We will present emerging results of our study across Greenland. A synthesis of these long-term analyses reveals a latitudinal effect, regional climate effects and local controls on long-term glacier mass balance. For example, local rates of loss across the Himalaya were enhanced with the presence of surface debris cover (by 2 times vs clean-ice) and/or a proglacial lake (by 2.5 times vs land-terminating).

Overall, we highlight the utility of geomorphological-based reconstructions of glaciers for understanding and quantifying long-term (centennial-scale) responses of mountain glaciers and ice caps to climate and hence for understanding of meltwater production and proglacial landscape evolution.

Catastrophic glacier volume loss on Juneau Icefield driven by non-linear processes

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Plateau icefields are sensitive to climate change due to the non-linear controls their topography imparts on their response to climate change. We used geomorphological mapping and structure-from-motion to reconstruct the extent, volume and velocity of Juneau Icefield during the “Little Ice Age” (1770), 1948 and 1979, and every ~10 years from 1979 to 2020 AD.

The study area included 1158 glaciers in 1770AD, covering 5405.91 ± 104.62 km^2 (1589.57 km^2 greater than in 2019). Total icefield volume loss (LIA to 2020AD) was 176.14 ± 27.22 $km^{3,}$ with the disappearance of 108 glaciers. Rates of recession 1770-1948 were -6.27 km^2 a^{-1}, volume loss was -0.12 ± 0.05 km^3 a^{-1}, and 97.14% of glaciers receded. From 1948-1979, glaciers receded at -5.53 km^2 a^{-1}, icefield-wide volume loss was -0.88 ± 0.20 km^3 a^{-1} and 31.84% of glaciers advanced. Several glaciers thickened slightly, with an advance of 1,486 m for Taku Glacier.

From 1979-1990, recession accelerated, reaching -7.95 km^2 a^{-1}, and 8.53% of glaciers advanced. Recession was -17.19 km^2 a^{-1} (1990-2005) and accelerated sharply after 2005, reaching -23.69 km^2 a^{-1} (2005-2015) and then -45.69 km^2 a^{-1} (2015-2019). This indicates an eight-fold increase in recession from 2015-2019 relative to 1948-1979, and a fivefold increase relative to 1979-1990.

Icefield-wide volume loss from 1979-2000 reached -3.00 ± 0.18 km^3 a^{-1}, -3.08 ± 1.01 km^3 a^{-1} (2000-2010), and -5.91 ± 0.80 km^3 a^{-1} (2010-2020). Thinning is now apparent at elevations of 1725 m asl on Gilkey Glacier and 1670 m asl on Meade Glacier, and thinning has now reached the plateau accumulation area. This has resulted in increasing glacier fragmentation, with disconnections between accumulation and ablation areas occurring with rapidly increasing frequency after 2005 AD, due to the ELA rising to areas of thin, steep, heavily crevassed ice. This study shows a glaciological threshold response to a warming climate and a rising ELA. Thinning on the plateau area is inducing rapid and accelerating recession of glacier tongues and fragmentation of the icefield. The non-linear behavior observed is highly concerning for the future viability of the icefield.

Glaciers in the Sierra Nevada, California are likely unprecedentedly small in the Holocene

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Glaciers in the Sierra Nevada, California, USA are thought to have disappeared in the early to mid-Holocene (~10,000–3,000 years ago) during peak Holocene summer warmth before subsequently reforming and advancing during late Holocene 'Neoglacial' cooling. The degree to which modern retreat is anomalous in the Holocene frames our understanding of climate change in California this century, with implications for water resources that affect biodiversity loss, agriculture, and human consumption. Here, we synthesize evidence from moraine surface exposure ages, distal lake sediment records, and new proglacial bedrock exposure ages that suggest Sierra Nevada glaciers existed through the Holocene and are only now disappearing.
We measured paired *in situ* ^{14}C and ^{10}Be concentrations in proglacial bedrock between modern ice and the Little Ice Age moraine at Conness, East Lyell, and Maclure glaciers, all in or bordering Yosemite National Park, California. Bedrock nuclide concentrations at the terminus of Conness Glacier (n=6) are near AMS system-blank levels for both ^{10}Be and ^{14}C measurements, suggesting that Conness was larger than its modern size (2018 CE) for the entire Holocene until present. ^{10}Be bedrock concentrations from the terminus of Maclure Glacier (n=3) are similarly near blank levels, suggesting it too has receded to an unprecedented minimum size in the Holocene. ^{10}Be exposure ages from bedrock at East Lyell Glacier (n=6) range from near-blank levels to ~1,700 years, incompatible with full deglaciation from 10–3 ka. Bedrock samples are from various locations of the glacier forefield, likely relating to the scatter in ages. ^{14}C ages for Lyell and Maclure Glaciers are forthcoming and will be presented at the meeting. At all three sites, moraine boulder ^{10}Be ages (n = 29) and lake sediment records suggest late Holocene glacier growth, which we use to explore plausible Holocene glacier length histories via numerical modeling of bedrock nuclide concentrations.

Holocene glacier chronology of the Southern Alps/New Zealand - A re-assessment based on Schmidt-hammer exposure-age dating (SHD) and geomorphological analysis

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The investigation of Holocene glacier chronologies has been recognised as one key element of research on mountain glaciations in the light of current global change because they can be utilised as high-resolution palaeoclimatic archives. During the past few decades considerable progress has been achieved, in particular due to substantial improvements of the ability to accurately date glacial landforms essential for subsequent analysis in the context of glacier advance/retreat periods. The Southern Alps of New Zealand are among the few suitable study sites for the investigation of Holocene glacier chronologies in the mid-latitudinal Southern Hemisphere that consequently have drawn attention.

Although a decent number of studies on this topic have been carried out in the Southern Alps so far, reviewing recent publications still reveals some problems related to the specific characteristics of this geomorphologically and climatically dynamic mountain region: (1) complex geomorphology of glacier forelands and their landforms affected by strong paraglacial modification, (2) influence of frequent mass movement events on moraine formation and (possibly) glacier response, (3) limited information on representativeness of local glacier records and resulting questions about the justification of amalgamated records, (4) few modern glaciological studies hampering proper palaeoclimatic interpretation and postulated Early Holocene glacier advances that do not really fit existing parallel records of other palaeoclimatic proxies, and (5) comparison of different approaches and their limited assessment in relation to older studies. As a result, even more recently published Holocene glacier chronologies from the Southern Alps do not necessarily pass critical assessment.

During a current research project several glacier forelands in the region were geomorphologically mapped/analysed along an extensive application of Schmidt-hammer exposure-age dating (SHD). Based on previously published age information local SHD calibration curves have been calculated and applied to extent the regional basis for the reconstruction of a reliable regional Holocene glacier chronology. Preliminary findings partly contrast to existing data, in particular do they generally point towards a reduced number of Holocene glacier advance periods (neoglacial events) than some studies previously claim. The complex geomorphology of many forelands requires a more careful interpretation of chronological data than often presented in related studies.

Cold control then precipitation control for Alpine glaciers (Le Tour and Argentière, Mont Blanc massif) in the Younger Dryas and early Holocene

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The last glacial Younger Dryas (YD) stadial outcome seems to be followed by an abrupt heatwave with augmenting temperatures that have reached 8 ± 7 C°, however, numerous moraines were actually formed afterward. Their construction is the result of readvances spatially and temporally closed from those belonging to the YD. To better understand this paradox, we studied the paleo-glacial margins from the haute Arve valley through geomorphological and geochronological methods to constraint the extents in a first time. In a second time, we defined climate conditions associated to different paleo-glacial extents with the help of a "Precipitation Degree Day" (PDD) model adjusted with a mass-balance law for 2 stadial : the Younger Dryas-Early Holocene transition (YD-EH) and the Early Holocene (EH).

A simple scenario is proposed, which is coherent with 35 10Be dating samples (including 20 news) and 2 14C ages : Argentière and Tour glaciers still formed the haute Arve valley glacier after the abrupt temperatures change after ~11.7 (i.e. they were still joined). The margin is defined by the moraines system of La Joux (10.7 ± 0.5 ka). They then retracted, coupled with the formation of proglacial/juxtaglacial lakes at the ancient confluence zone. Sediments of the lake were covered by the moraine of Tré le champs le bas where new samples are dated (9.6 ± 0.6 ka), belonging to the Holocene. Furthermore, this advance was less important than the YD one, and preceded by a glacial retreat around 12.180-10.834 ka Cal. BP (14 C, Intcal20).

The PDD model parameters were calibrated using the Tour and Argentière mass-balances in order to look for precipitation x temperatures combinations and reconstruct the climate conditions of two stadials : La Joux and Tré le champs le bas in order to evaluate how it evolved during a transition between glacial and interglacial periods. The results suggest extents of alpine glaciers in the Mont Blanc massif has been consecutively controlled by a persisting cold post YD more intense comparing to today's, followed by an increase of precipitations during the Holocene, superimposed to cold peaks less intense than YD.

Insights on a wet Alpine Younger Dryas: new data from the Italian Dolomites (southern Eastern Alps)

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The Alpine Lateglacial was punctuated by mild interstadials and cold stadials, the youngest (12.8-11.7 ka, in the European Alps) being the Younger Dryas (YD) and corresponding to the last glacier readvance before the Holocene. Temperature reconstructions suggest the YD being 3-5°C colder than today. Paleoprecipitation patterns during YD are debated, but there is agreement on a 20-30% lowering in the central part of the Alps. However, no data are available for the whole eastern side of the Alps, where our study area is located.

We studied the YD glacial deposits in the Venegia Valley (Italian Dolomites), where a small glacier still survives (Travignolo glacier). During the YD, this glacier was merged with two others, forming a 6 km-long tongue. At its front, it built a well-expressed morainic arc, made of at least three main ridges. The shape and size of the glacier, as well as cosmogenic dates obtained from boulders on the frontal moraines, confirm these arcs to be YD in age. We reconstructed both the YD and LIA glacier extents, obtaining also the associated ELAs using the GlaRe GIS toolbox. These data allow for an inference of paleoprecipitations occurring at the YD by means of the empirical diagram developed by Ohmura and Boettcher, and utilising independent summer temperature reconstructions. Results suggest precipitations were relatively high at the study site during the YD, though it remains unclear whether this was in terms of annual or seasonal (snowy) precipitation.

Late-glacial and Holocene glaciers and snowpack in the High Atlas Mountains, Morocco

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Pleistocene glaciations of the Last Glacial Cycle in the High Atlas Mountains are well documented and widespread, extending into lower valley areas below altitudes of 2000 m. In the Toubkal Massif (4167 m) of the Marrakech High Atlas, glaciers reached 5-10 km in length and formed plateau icefields over the drainage divides. In the Late-glacial and Younger Dryas, cirque glaciers persisted. Today, only a few snowpatches survive summer melting though perennial snowpatches and potentially, small niche glaciers, were far more widespread during the 19th and 20th century. Evidence for these former snowpatches and niche glaciers has been mapped, and ^{36}Cl and ^{10}Be terrestrial cosmogenic nuclide exposure dating has been applied to successive moraines from the cirque headwalls and down-valley. A key focus is to compare the extent and climatic significance of Holocene glaciers with Late-glacial and earlier Pleistocene counterparts. It is unclear presently whether the largest Holocene glaciers and perennial snowpatches belong to the Early-Mid Holocene or the Little Ice Age. Available palaeoenvironmental evidence from sediment sequences from nearby marsh and lake records at Oukaïmeden and on the Yagour Plateau, respectively, can complement the geomorphological and exposure dating record. In the High Atlas, the Little Ice Age was characterised by wetter conditions than today and coupled with slightly cooler summer conditions. This may have favoured the survival of perennial snowpatches and niche glaciers. However, other cool/wet episodes are recorded through the Holocene based on the continuous sediment record from the Yagour Plateau. The relationship between snowmelt and climate is reconstructed using degree-day modelling. It is clear from this that the reconstructed regional equilibrium line altitude for glaciers throughout the Holocene, and also today, is above the highest peaks. Hence niche glaciers and indeed perennial snowpatches, would have all existed under strong topoclimatic controls and valley-to-valley microclimatic differences, where large potential melt was offset by shading and avalanching snow. This topoclimatic complexity was combined with other influencing factors such as localised cooling over perennial snow/ice surfaces in topographic hollows and also debris cover.

Late Pleistocene glacial history of the Black Forest, southern Germany, and implications for past atmospheric circulation patterns

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During the Late Pleistocene, an ice cap and its up to 25 km-long outlet glaciers temporarily covered the highest summit of the Black Forest, Feldberg (1493 m above sea-level) and the surrounding region. During deglaciation, the ice cap disintegrated into valley glaciers with independent accumulation areas. Valley glaciers finally evolved into cirque glaciers. Despite recent efforts, the chronology of Late Pleistocene glacier fluctuations in the Black Forest is not sufficiently understood. In particular, the timing of glacial re-advances or standstills at the end of the deglaciation remains largely unknown. The onset of glacier retreat from the Late Pleistocene maximum ice extent has hitherto not been successfully dated.

This study addresses these issues by applying ^{10}Be cosmic-ray exposure (CRE) dating to moraines at three sites. Newly acquired chronological data imply that glacier retreat from the moraines of the marine isotope stage (MIS) 2 maximum advance was underway by 21 ka at the latest when glacier recession in the Swiss Alpine Foreland had already begun. Recalculated ages for the Bavarian Forest suggest that glaciers in the Bavarian Forest and in the Black Forest might have withdrawn simultaneously from their MIS 2 maximum positions. Within the limits of available data, CRE ages suggest that glaciers in both regions attained their MIS 2 maximum extent when a westerly atmospheric circulation re-established over Central Europe. To confirm these hypotheses, additional data for the Black Forest is needed. Ages of moraines at two sites fall into the Lateglacial.

Glaciers and equilibrium line altitudes (ELAs) during moraine formation were reconstructed for paleoclimatic inferences. ELA-based reconstructions of paleoprecipitation for the youngest ice-marginal positions were undertaken with data from two independent summer temperature records. Unrealistically high annual precipitation during the Lateglacial would have been required to balance summer temperatures at the ELA. Even if all potential errors of the reconstruction are taken into account, it seems unlikely that glaciers still existed in the Black Forest after the abrupt rise in summer temperature at ~14.6 ka. Therefore, deglaciation was likely completed during this climatic event or before.

Synchronous Last Glacial Maximum advances of large and small palaeoglaciers in the Maritime Alps

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The Maritime Alps represent the southernmost sector of the Western European Alps (NW-Italy, SE-France). During the Last Glacial Maximum (LGM), this mountain range hosted both large valley glaciers in the order of several hundred km^2, but also smaller glaciers that remained confined to side valleys or cirques. Owing to their location, in close proximity to the Gulf of Genoa, the glaciers in the Maritime Alps were strongly influenced by Western Mediterranean atmospheric circulation. Reconstructing their past extents and Equilibrium Line Altitudes (ELAs) can therefore be used as a proxy to track changes in this circulation over time.

During the past decades, multiple geomorphological surveys have been carried out in the Maritime Alps to map glacial features and to constrain LGM ice advances through numerical dating methods. However, these studies have primarily focused on the large glacial systems in the Stura and Gesso valleys. The evolution of smaller (and likely more responsive) palaeoglaciers and their ELAs, on the other hand, are less well constrained. Additionally, it remains unclear if these smaller glaciers advanced synchronously with the larger Stura and Gesso systems.

To address these questions, we present new data from three small LGM mountain glaciers, located on both northern and southern sides of the Maritime Alps. Palaeoglacier 3D geometries and ELAs were reconstructed using GIS-tools based on previous geomorphological surveys, while age control is provided through new ^{10}Be cosmogenic exposure dating of moraine boulders. We demonstrate that moraines in the Maritime Alps record a two-fold LGM advance and that, within the dating uncertainties, the small glaciers advanced synchronously to the larger valley systems both in the Maritime Alps and beyond. Additionally, reconstructed ELAs are discussed in the context of the LGM palaeoclimate of the southern side of the Alps and the wider Western Mediterranean region.

Mountain glacier fluctuations in the Glen of Imaal, Ireland, during the Last Glacial Maximum and Heinrich Stadial 1

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Projecting accurately the sensitivity of Earth's ice sheets to future warming is dependent on our understanding of past ice sheet response to climate shifts. Recent work focused on offshore and near-shore glacial sediments in the northeastern North Atlantic provides insight into the dynamics, and ultimate demise, of the ice sheet that once covered Britain and Ireland during the Last Glacial Maximum. However, ground-truthed chronologic information on the terrestrial pattern of British-Irish Ice Sheet (BIIS) retreat remains relatively sparse, thus limiting our ability to reconstruct ice sheet response to Quaternary climate changes. Ireland hosts an array of glacial landforms that attest to the former terrestrial extent of both the BIIS and to the numerous mountain glaciers that remained after the ice sheet itself had receded. Here we report a new glacial chronology from the Glen of Imaal, in Ireland's Wicklow Mountains, constrained with cosmogenic beryllium-10 surface-exposure ages of moraines and erratic boulders. These data provide direct chronologic constraint on the extent and timing of mountain glacier fluctuations at the Glen of Imaal and indicate that mountain glaciation was most extensive at the site approximately 23 ka, after which protracted retreat began. Our data also suggest that glaciers may have disappeared from the catchment entirely during Heinrich Stadial 1. Because mountain glaciers can exist only in the absence of an overlying ice sheet, the ages of these mountain glacier moraines place a minimum limiting age on the timing of ice sheet retreat in the southern Wicklow Mountains. These data offer new insight into the response of Ireland's cryosphere to past climate change and provide discrete terrestrial targets for ice sheet and glacial modelers investigating the response of these ice masses to changing climate conditions.

Past debris-charged plateau icefields in the Godeanu Mountains, Southern Carpathians, Romania

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Reconstructing the extent, style, timing and drivers of past mountain glaciation is crucial in both understanding past atmospheric circulation and predicting future climate change. Unlike in high-elevation mountains situated in maritime and continental climates, less is known of past glaciation in mid-altitude mountains, located in transitional climates, such as the Southern Carpathians of Romania. Despite these mountains harbouring a rich glacial geomorphology, this has never been systematically mapped according to well-established morphological criteria, nor confidently related to former styles of glaciation. Therefore, filling this gap is important for not only accurately identifying glacial extents, but also for establishing past glaciation styles and relating them to past ice dynamics and climate. Here, we aim to devise the first glacial landsystem model for the Southern Carpathians (the debris-charged plateau icefield landsystem) to enhance our understanding of the glaciation style and dynamics of past mountain glaciers in temperate-continental climates. Using a geomorphologically-rich mountain range, the Godeanu Mountains in the Southern Carpathians, as a case study, we will first present a remote- and field-based geomorphological map of the study area, whereby we identify and interpret between mountain landforms of glacial, periglacial and paraglacial origin. Secondly, we will infer both the origin and the transport pathways of selected, ground-truthed glacial landforms, by analysing their sedimentology. Furthermore, we hypothesise the relationship between the mountain geomorphology and glaciation style and dynamics, based on the spatial linkages between the landforms in the study area, through the glacial landsystem model. Finally, we assess the implications of the glacial landsystem model for the geomorphology and ice dynamics in other areas of the Southern Carpathians and beyond.

Paleoglacier and -climate reconstructions on the Eastern Black Sea Mountains, obtained from Parallel Ice Sheet Model (PISM)

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Investigating disappearing glaciers due to recent climate changes and examining their past records provide feedback for future climate predictions. In recent years, the efforts to investigate the existence of paleoglaciers in Turkey have been increasing. Dating studies using cosmogenic isotopes provide significant information about the timing of paleoglaciers, especially for the Last Glacial Period. These studies have shown that the Anatolian paleoglaciers mostly reached their largest extents during the Last Glacial Maximum (LGM, ~ 21 ka ago) and then retreated to their successive positions. However, in some regions, the maximum conditions have occurred much earlier. One of them is the Eastern Black Sea Mountains of Turkey. In this study, a physical glacial flow model was used to understand why the Eastern Black Sea Mountains behaved differently. The study area covers the most rugged and glaciated part of the Black Sea region. We used an open-source software called Parallel Ice Sheet Model (PISM), to model the paleotemperature and paleoprecipitation conditions during the last glaciation. First, we changed the current climatic conditions in the region, and then three-dimensional glacier reconstructions were created using manipulated ice mass balance conditions in PISM. The paleoglacier extents obtained in previous studies via elevation of lateral and terminal moraines, and trim lines were compared with the model results to determine the paleoclimatic conditions of the glaciers. Here, the preliminary results of our project funded through a TUBITAK grant (#121Y507) will be presented.

Glacial chronology north of Lake Issyk-Kul in the Kyrgyz Tian Shan using cosmogenic nuclide dating

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There is ongoing debate over the mechanisms driving glaciation in the Tian Shan in Central Asia. Quantitatively dated glacial chronologies provide critical information for models exploring possible influencing factors. Compared to other glaciated regions of the world, the Tian Shan has relatively few dated glacial features, with significant discrepancies present between existing studies.

This study presents dates on glacial features in Chon-Koi-Su Canyon located in the Tian Shan north of Lake Issyk-Kul. Using cosmogenic chlorine-36, 25 samples from moraines in the valley showed three distinct advances. The Last Glacial Maximum (LGM) advance was extensive (>8km downvalley) when many other glacial chronologies in the area do not identify a significant/any advance at this time. The dates from the oldest moraine aligns well with youngest of three 10Be-dated terraces nearby, potentially extending the glacial chronology to even older events. This well-dated glacial chronology, including an extensive LGM advance, contributes a new dataset in a previously undated area of the Tian Shan, providing new insight into the ongoing debate over the factors controlling glaciation in the Tian Shan.

Asymmetries within the Pyrenees and correlation across the westernmost European mountain ranges. Glaciation typologies

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In the last glacial cycle, glacier expansion started as early as MIS 5d in the Mediterranean region, followed by a notably abrupt cooling in MIS 4 that lasted no more than about ~10 ka, in contrast with the ~16 ka of MIS 2, within which the Last Glacial Maximum (LGM) phase took place centred at 22.1 ± 4.3 ka. Noticeable from the Pyrenees was a last maximum ice extent (LMIE) predating the LGM from northern ice sheets, a pioneering European mountain area underlining this asymmetry. Besides, we point to several distinctive traits encompassing chronology and glacial dynamics. I - A Penultimate glacial cycle during MIS 6 and older glacio-fluvial terraces beyond the range of the luminescence dating method. II – An early glacial advance in MIS 5d (~97 $_{-15}\backslash^{+19}$ ka) followed by glacier retreat during MIS 5c (< 91 ± 9 ka). III – The last maximum ice extent (LMIE) is from the early MIS 4 (~74 ± 4.5 ka). IV – Glaciers thinned during the second half of MIS 3 (~39 $_{-6}\backslash^{+11}$ ka). V – During the MIS 3 – MIS 2 transition, glaciers were highly sensitive to climate fluctuation. VI – The Last Glacial Maximum (LGM) is always back an end moraine built previously and, in some cases, was characterised by the construction of nested moraines. Our research unravels the main glacial phases in the Pyrenees, a region in SW Europe of significant relevance in connection with the last glacial cycle (LGC). By comparing our results with those from other mountain ranges in Portugal, Spain, and France, we recognise patterns highlighting portions of the LGC or all of it and outlined above, as follows: (A) areas where glaciers were relevant during MIS 2, some of them (B) including a far-flung end moraine produced in previous glacial phases (early Würm or Riss), (C) areas showing a pseudo-pleniglacial condition, (D) multi-phase glacier advances, (E) those showing the relevant presence of glaciers during Termination-I.

Moisture control on LGM atmospheric lapse rates: a model – data comparison in the American Cordillera

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Reconstructing spatial and temporal variations of the vertical atmospheric temperature gradient (lapse rate, "LR") is key to anticipate the future climate of high-altitude regions. This parameter may amplify or mitigate the future warming at high elevation, implying contrasted impacts on the stability of glaciers. Several regional studies suggested that the tropical LR was steeper than today during the last glacial maximum (LGM) (Loomis et al., 2017; Blard et al., 2007), while other studies concluded that the LGM lapse rate was similar than today (Tripati et al., 2014). Here we present a new compilation of glacier-based temperature reconstructions at high elevation (> 2500 m) for the LGM, which are compared to synchronous changes of sea surface temperatures (Pacific Ocean), along the American Cordillera, from 40°S to 40°N.

This new reconstruction confirms that lapse rates were steeper in the regions that were drier than today during the LGM. This corresponds to an amplification of cooling at high altitude during the LGM. To further analyze this observation, we also use the IPSL global climate model PMIP4 results (Kageyama et al., 2021), which, in agreement with the reconstructions, yields a steeper tropical lapse rate in its LGM simulation, compared with the pre-industrial one. Next, we disentangle the impacts of the lower atmospheric CO_2 concentration and of lower humidity using a single column radiative-convective equilibrium model (Kluft et al., 2019), and show the strong impact of changes in humidity in the tropical lapse rate steepening at the LGM.

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Session 24: Fluid venting as a submarine geomorphic process

Seafloor fluid vents imaged by 3D seismic data on the upper Amazon deep-sea fan

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Submarine gas hydrate systems are increasingly recognised to be associated with seafloor features recording the venting of gas-rich fluids to the deep ocean. The Amazon deep-sea fan contains a gas hydrate system characterised by a discontinuous bottom simulating reflection (BSR) forming elongate patches that follow the crests of thrust-folds within an upper slope (500-2250 m) compressional belt related to the gravitational collapse of the fan. Multibeam hydroacoustic data have previously shown the upper slope to be associated with dozens of water column gas flares, most rising from high backscatter seafloor mounds from two of which gas hydrates have been sampled. Here we present examples of seafloor features observed using bathymetry derived from extracts of a commercial 3D seismic volume (10 m grid resolution). In places, the data reveal fields of sub-circular morphological features up to tens of meters in relief and hundreds of meters in width. The features include a variety of positive and negative morphologies, including mounds, depressions, and mounds within depressions. The morphology of the mounds allows them to be interpreted as small mud volcanoes, some with crater-like depressions at their summits; some mud volcanoes sit within larger depressions interpreted to represent calderas due to localised subsidence. A few unfilled depressions are observed and may be calderas or large pockmarks. Seismic profiles show the seafloor features to be underlain by chaotic vertical columns consistent with plumbing systems, which pass through the BSR patches to root in subjacent thrust-folds. Some seafloor features, or groups of features, are associated with 'pluming' BSRs that indicate the rise of warm fluids; however, only a few coincide with water column gas flares previously identified on multibeam imagery, possibly reflecting episodic activity. The surprising variety of relatively small extrusive morphologies observed on the upper Amazon fan underscores the potential of high resolution seafloor datasets to provide new insights into the processes and products of deep-sea fluid venting.

REE and trace elements behavior in shallow hydrothermal vents sourrounding Panarea island (Italy)

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Exploration of Shallow Hydrothermal Vents (SHV_s) is usually focused on analysis of major chemical species while contents of trace and Rare Earth Elements play an important role as tracers both of natural and anthropic geochemical processes.

Here we show progresses concerning trace elements and REE geochemistry in natural system focusing on their geochemical behavior in SHVs (shallow hydrothermal vents) in the surrounding area of Panarea Island (Eolian Islands, Italy).

Samples were collected from submerged vents at different depth (5-40m) and analyzed for Al, V, Mn, Fe, Ni, As, Ba, Pb and REE from June 2015 to July 2022.

Physical-chemical parameters span in a wide range of values: pH 2.7–8.2 and -235–186 mV for pH and Eh respectively; this variability is responsible of the variations in concentrations of Fe, Al, Mn and total REE concentration (REE_s) as an inverse correlation in observed between pH and Fe-Al-Mn and between pH and REE_s.

The pH values play a controlling role on the precipitation/dissolution of solid phases, inducing a fractionation of REE. The positive correlation between REE_s and Fe-Al-Mn in fluid samples shows the simultaneous variations of these elements linked to co-precipitation and adsorption onto the surface of oxide and oxyhydroxide of Fe, Al and Mn involving process of REE scavenging controlling their abundance dissolved in hydrothermal fluids.

REE Patterns show two different trends and according to the pattern shapes, waters could be classified in two groups: group-1 ($LREE_n/HREE_n>1$) showing decreasing trend from La to Lu (carbonate complexation of REE) and group-2 ($LREE_n/HREE_n<1$), characterized by Light REE depletion (adsorption to Al, Fe and Mn-oxyhydroxides).

Plotting $LREE_n/HREE_n$ vs REE_s, a hyperbolic array is composed by two end-members: EM1 characterized by higher $LREE_n/HREE_n$ and low Fe, Al and Mn concentrations; EM2 with Lower $LREE_n/HREE_n$ and high Fe, Al and Mn concentrations.

All these evidences demonstrate that the contamination of discharging fluids and consequent formation of Fe, Al and Mn-bearing minerals controls the fractionation of REE and trace elements. As a result, the fate of trace metals and REE is mainly conveyed by both processes of scavenging onto newly forming Fe-Mn-Al-oxyhydroxides and carbonate complexation.

Submarine geomorphology offshore Crotone (Calabrian Accretionary Prism): the contribution of fluid expulsion and sediment mobilization

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Accretionary prisms originate at active subductive margins and grow mainly through the piling of sediments scraped from the subducting plate. During this process these sediments are progressively buried and squeezed, leading to fluid expulsion and often sediment mobilization. As a result, fluid venting, mud volcanoes and mud diapirs are common features in accretionary prisms worldwide. Subduction zones are present within the Mediterranean region, involving residual portions of the Tethyan oceans that have survived Aftica-Europe continental collision. One of these subduction zones is located underneath Calabria and give rise to the narrow Calabrian Arc accretionary prism, that covers most of the Ionian Sea and is confined on either side, east and west, by the Apulian and Malta escarpments, respectively. Mud volcanoes are known from long time to populate the inner Calabrian accretionary prism, and it is likely that their number is still largely underestimated. Few of these mud volcanoes have been extensively studied, revealing the occurrence of thermogenic gas and of microfossil assemblages ranging from Late Cretaceous to Recent. The Ionian Sea offshore of the Crotone promontory offers examples where the expressions of fluid expulsion and sediment mobilization are visible both in the subsurface and at the seafloor. The analysis of morphobathymetries at variable resolution and public domain and proprietary seismic data, including 3D seismic cubes, allows to characterize systems of mud diapirs, both active and fossil, and their relationships with trains of pockmarks. Mud pools and pockmarks are direct expression at the seafloor of fluid expulsion but in some instances they also contribute to destabilize the uppermost sedimentary strata, triggering small landslides. A fossil mud diapir-mud pool system has also been identified; it is sealed by relatively undeformed sedimentary strata, allowing to constrain a minimum age range for the onset of fluid expulsion and sediment mobilization.

Integration of morphobathymetric data and ROV observations for the study of fluid-related features offshore Scoglio d'Affrica islet (Northern Tyrrhenian Sea)

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Fluid seepage from the seafloor is a common process that has been reported worldwide from coastal to deep-sea environments. Scoglio d'Affrica islet is located in the southernmost part of the Elba-Pianosa Ridge, a north-south elongated morpho-structural high separating the Tuscany margin from the Corsica Basin in the northern Tyrrhenian Sea. Submarine fluid emissions have been documented in this area since late '60, including a violent gas outburst occurred in 2017 offshore Scoglio d'Affrica islet. High-resolution bathymetric surveys performed after the event revealed the widespread occurrence of fluid-related morphological features, encompassing several mud volcanoes with different size and shape and hundreds of pockmarks. In this work, we present the results of the integration of morphobathymetric data with ROV observations collected in the area in 2017 and 2021. ROV videos showed a large variability in the seafloor characteristics of the mud volcanoes across the study area. A prevalent sandy seafloor with local accumulation of mud breccia characterized the top of larger edifices, while in other cases the videos recorded the presence of large boulders partially or totally covered by *Posidonia oceanica* meadows, which was widespread in the area. Active seepage via both continuous and intermittent bubble release from the seafloor was observed on videos, with venting points distributed over different features and seafloor types. The integration of morphobathymetric data with small scale information from video footage provides insights into the seafloor-shaping processes linked to fluid seepage around Scoglio d'Affrica islet. This is a particularly relevant issue considering both the paucity of studies on shallow-water mud volcanoes as well as the hazard associated with violent gas outbursts in such settings.

Session 25: Islands and their relationship with the continent to investigate time and mode of their colonization by terrestrial vertebrates and Homo dispersal

Coastline evolution in Sicily using archaeological data between 15 and 7 ka cal BP

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The peculiar paleo-geographic evolution of Sicily, the main Mediterranean island, makes it a perfect environment to study the relationship among early peopling, marine environment and coastal changes through the last millennia. One of the main issue debated from ancient topographers and archaeologists dealing with human mobility, ancient viability and paleo environmental studies is the actual morphology of the coastline depending from relative sea level-change that deeply changed from 15 ka cal BP (-101 m), 11 ka cal BP (-56.6) and 7 ka cal BP (-10.3 m) (Lambeck et al., 2011) directly influencing palaeocostlines, topographic and historical interpretations. Our research aims at filling this gap, offering valid variables to territorial models eventually combining archaeological survey and excavation data with the actual ancient coastal morphology and the related distance from archaeological sites: all decisive factors for a precise palaeoenvironmental contextualization of the archaeological data and the reconstruction of littoral resource exploitation patterns, human occupation, and mobility patterns along the coasts.

In order to achieve our scope we have georeferred the main archeological sites along the modern coastline of Sicily with a chronology spanning from the documented early peopling of the island (~ 17 ka cal BP) to the Neolithic. Then we take into consideration morphobathymetric, lithological and sea level change (both isostatic and tectonic), in order to reconstruct the ancient coastal morphology, the distance and altitude of sites from and on the sea and, in some cases, the eventual existence of submerged archeological deposits or features at five specific case study: Grotta del Tuono and Cala del Genovese (Egadi, Trapani), Baia dell'Uzzo (San Vito Lo Capo, Trapani), Grotta dell'Arco di Capo Zafferano (Bagheria, Palermo) and Riparo del Castello (Termini Imerese, Palermo).

SEAcross: A tool to measure the performance of large mammals in crossing sea straits

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Reconstructing dispersals of paleo-species often suffers from low data coverage, leaving wide gaps in space and time. Data often is extremely punctual. In such cases, simulation-based approaches like agent-based modelling may support testing hypotheses about course, speed and/or range of specific dispersal events. We developed the SEAcross ABM to test dispersal performances of terrestrial mammals in archipelagos. The agents cover sea straits by quadrupedal paddling, a swimming style accomplished by all terrestrial mammals. Body mass and size of the agents determine their swimming performance, particularly range and speed of movement in water. Additionally, the agents may differ in their hydrophobia score, i.e. their preparedness to start a crossing attempt, and the group size required to rate crossing attempts as successful. The model also allows to accommodate sea straits of different width, and current speed and direction.
We applied the SEAcross ABM in a suite of experiments, mainly focusing on Southeast Asia and Wallacea, to demonstrate its flexibility. It can be applied to examine dispersal routes and ranges of individual species, for instance the dispersal of stegodons across insular Southeast Asia and Wallacea. In this case, a shrinking model is included to accommodate for island dwarfing, because size critically influences dispersal performances. As a result, we were able to identify potential routes, and compare the range with the known fossil record. Moreover, it can also be applied to examine the fossil record of mammalian taxa in specific islands, where the faunas are composed of a mixture of migrants originating from mainland Southeast Asia and Meganesia. Data emerging from the SEAcross ABM can then be validated by the fossil record. Some of the results will be introduced and discussed here.

New insights into the Late Pleistocene climate of Malta: Microfaunal analysis from Għar il-Fkieren

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The Maltese Islands are known to have hosted a much more vibrant and biodiverse range of species during the Pleistocene than they do today, such as pygmy elephants, giant swans, and large dormice. However, most of what is known about Malta's Pleistocene fauna originates from excavations undertaken at the Għar Dalam cave site using rudimentary methods over a century ago. Għar il-Fkieren, a newly-discovered Quaternary site replete with faunal remains, now provides the opportunity to gain independent insights into the climate conditions, faunal complexes, and biogeographical history of the Maltese islands during the Late Pleistocene. Here we present a study on the microfauna from this site with a special focus on rodents. Microfauna, with their small home ranges, restricted habitat, and high reproductive rates, are excellent proxies for local environments and environmental change. While their use as proxies has long been recognised, microfauna have not yet been studied with a view to understanding climate history in Maltese contexts. We combine here microfauna taxonomy, morphometry, and stable isotope analysis to provide an unprecedented insight into the environmental and climatic conditions during the Late Pleistocene on the Maltese Islands.

Island time. Exploring human-animal interactions during the Pleistocene in the Wallacean Islands

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Research in the Wallacean islands, the biogeographic region separating the Asian and Australian continental shelves, has provided insights into the antiquity of human occupations, migratory routes, navigation techniques, and artistic manifestations. Furthermore, recent genetic studies, as well as evidence of the diversity of cultural practices, illustrate the research potential of this region.

Human-animal interactions in these insular environments are sometimes difficult to assess. Differences in the type of existing vertebrate fauna prior to AMH occupations, as well as the depauperated terrestrial fauna in some of these environments, requires systematic and individualized research approaches. The rich Pleistocene terrestrial fauna in islands like Java, Flores, Sulawesi or Kalimatan contrasts with the limited terrestrial resources available for AMH survival in Timor, Alor and Kisar. Additionally, most of the archaeological sites identified in these islands are located in cave systems, which contribute to difficulties to interpret the agent responsible for some of the faunal assemblages documented.

In this presentation, I will provide a brief overview of recent advances in the study of human-animal interactions in the Wallacean Islands during the Pleistocene. This talk will demonstrate how geometric morphometrics, osteometric, geospatial and taphonomical methods can contribute to achieve a better understanding of AMH animal resources management and interaction with their environment when they reached these islands on their way to the Sahul continental shelf.

Interactions between humans and dwarf elephants: a chronological perspective

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Multiple examples of insular dwarfism, such as that observed in the fossil record for Pleistocene elephants, provide one of the most intriguing ‘natural experiments’ in parallel evolution. The corollary to this, which has received less focus, is that it also provides a study system for examining the drivers of extinction. Critically, the turnover events (faunal extinction, followed by renewal) observed across several hundred thousand years on islands such as Sicily, Malta, Crete and Cyprus provide an opportunity for assessing a baseline extinction risk for vulnerable populations. Human activity has been invoked as the main driver of extinction for *Palaeoloxodon (Elephas) cypriotes* on Cyprus. However, the extinction of pre-Holocene insular forms is largely assumed to have occurred in the absence of humans. One key issue here is that the evidence for interactions between humans and insular endemic species are largely inferred from chronological overlap, yet the chronologies are far from robust. Here we will present an overview of our current best understanding of the geochronology of Mediterranean dwarf elephant, deer and hippopotamus, and place this in the context of human activity on those same islands, and the neighbouring mainland. In doing so, we will highlight the degree to which we can be confident that these endemic fauna and humans did –and did not– overlap, and what this means for our understanding of human impact on both the evolution and extinction of mammalian fauna.

The Acheulean settlement of Lesbos Island: An Edaphics Approach

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The Aegean Sea has for long been envisioned in Pleistocene geography as a natural water barrier and as a 'cul de sac' in the discussion about the early hominin out of Africa dispersals. Recent work on the submerged landscapes of the Aegean led to the production of reliable palaeogeographical reconstructions for the past 400 Ka revealing a completely different picture. Large parts of the Aegean seabed now lying underwater, were subaerially exposed during the glacial lowstands most possibly since the Late Pliocene/Early Pleistocene and throughout the Pleistocene. Extended terrestrial environments created land bridges connecting western Asia to the Greek mainland and W Europe via the Aegean. Only recently this aspect started to gain ground in the discussion about the early Eurasian settlements, highlighting the biogeographical significance of the Aegean at the crossroads between three continents.

Robust archaeological evidence from Lesbos Island, NE Aegean, attributed to the Acheulean, attests to such crossings of hominin groups from W Asia to the Aegean. Absolute chronology methods (pIRIR, palaeomagnetism) offer minimum ages for the presence and activity of hominins on Lesbos between 476 and 164 Ka, in the second half of the Middle Pleistocene, while relative chronology (techno-typological comparisons) shows clear affinities with Early Middle Pleistocene Acheulean assemblages from C Anatolia, Israel and E Africa. The rich, and unique in NE Mediterranean, Palaeolithic Lesbos lithic assemblage, both excavated from fluvio-lacustrine deposits and collected from the surface of the Kalloni basin, reveal Acheulean variants covering the wide chronological span of this tradition. Hominin groups were returning recurrently to S Lesbos during the Middle Pleistocene. What attracted them there?

Here we apply an edaphics approach to S Lesbos to shed light on the hominin-landscape interaction. We examine the inputs of complex topography, volcanic landscape resources, including hot springs, and permanent and ephemeral water bodies to the Acheulean settlement and land use. The distribution of soil nutrients, vital for sustaining plant and animal populations over the modern landscape, is used as a proxy to decipher the ecological value of the Middle Pleistocene landscape and its affordances, through the identification of attractive/unattractive areas.

A Quaternary Galapagos: Mediterranean Islands in the Pleistocene and Holocene

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The Mediterranean region connects three continents, Europe, Africa and Asia. Changes in sea level meant that, at times, islands connected to the mainland, and formed stepping stones that circumvented longer coastal routes to link different regions of the Mediterranean. In turn, periods of sea level rise often drove intense processes of selection on islands, with biogeographic legacies sometimes lasting into the present day. These dynamic connections and periods of isolation have created a theatre of evolution that was ultimately interrupted by successive waves of humans and periods of climatic changes. Endemic species began to go extinct, in some instances replaced by analogous species translocated by humans from different mainland regions. This talk synthesises the available 'big picture' data on the Quaternary of Mediterranean Islands, using recent advances to coalesce the state of knowledge into a series of key questions. These concern long-term patterns of landscape change, tectonics and sea level rise, ecosystem resilience, the directionality and timing of faunal exchanges, processes of evolution, and ultimately, the transition to human dominated landscapes. These island transitions at the nexus of three continents are then used as lessons for understanding broader questions relating to the Anthropocene and today's biodiversity crisis.

Plants and animals use on islands. Limits, strategies, and adaptation from an archaeobotanical and archaeozoological perspective

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Islands have been considered models for archaeological research because of their nodal role within the wider networks of coastal and maritime sites. The limitedness of their area and resources and the need to forefront short- or long-distance voyages to reach them make islands more or less isolated, at least for some natural and cultural processes, particularly affecting local terrestrial plant and animal assemblages. This physical separation from the mainland often makes island ecosystems follow their own peculiar dynamics, and consequently humans had to cope with these constraints. Island human communities all over the world and through different chronological phases have then adopted special subsistence strategies to live in these territories, sometimes more successfully and other times ending their occupation with the abandonment. Here we present to present the most recent results of ongoing archaeobotanical (anthracological and carpological) and archaeozoological analyses on some Mediterranean (mostly Ustica, Aeolian Islands, Pantelleria) and northeastern Atlantic (Canary) Islands. Our goal is to compare islands of different size, distance from the mainland or other islands, geologic origin, reachability through sailing, plant and animal diversity to detect the patterns of adaptation of human communities to island features. We will focus on:

-the process and integration/impact of faunal (mammal) species introduction to the island environments

-the specific strategies of management of insular wood resources, i.e. the adaptation of human communities to cope with some specific features of local vegetation

-the selection of domestic animal breeds and size for sustainability

-the displacement of native animals from/to the mainland or other islands

-the genetic isolation of and use of storage systems

-the import of plant staple resources

-the specific exploitation of local wild fauna

-the indicators of local climate changes and adaptation

-the ethnobotanical evidence of centennial/millennial local agricultural customs.

Session 27: Resilience versus collapse: Human responses to climate change in the Quaternary

Towards an improved understanding of Late Pleistocene and Holocene vegetation dynamics, resource exploitation and the resilience of human communities in the south-central Peruvian Andes

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We present new palaeoenvironmental data from three wetlands located in the south-central Peruvian Andes. Laguna Runtoccocha is a lake basin formed within a small moraine at 4150 m (Apurimac) with a sedimentary sequence spanning the last ~15,500 years. Ayapampa is a small peatland (Apurimac; 3400 m) and Laguna Tocsaccocha (Ayacucho; 2290 m) is a partially infilled lake basin; both located in the Chicha-Soras Valley. They have sedimentary records spanning the last ~3500 and ~1600 years respectively. The pollen-stratigraphic data from Laguna Runtoccocha suggests that the Late Pleistocene landscape was characterised by open puna grassland as well as discontinuous montane taxa. We believe that the vegetation was responding to increased moisture availability on the puna resulting in an upslope shift in ecotonal boundaries possibly during the Lateglacial Interstadial (~14,700-13,000 cal yrs BP). An expansion of puna taxa, especially grassland, and a decline in arboreal taxa, denoted the transition to the Early Holocene. Together with the higher incidence of wildfires suggested by the charcoal concentrations, collectively this indicates an environmental response to Early Holocene climate warming and possibly lower precipitation. The Middle Holocene was characterised by a rise in xerophytic taxa suggesting a broader environmental response to higher temperatures and/or lower precipitation. The onset of the Late Holocene appears to be a change in the earlier aridification trend with evidence for increased moisture availability. Peat accumulation rates increase at Laguna Runtoccocha and sedimentation initiated at Ayapampa and Laguna Tocsaccocha. These records have permitted an evaluation of the relationships between climate variability, environmental change and cultural development, especially during the Late Holocene. During this period, human activities, especially those associated with terrace agriculture, transformed the landscape and environment. The records provide unequivocal evidence for the cultivation of *Zea mays*, and possibly other taxa, during the Middle Horizon, late Late Intermediate Period and Late Horizon cultural periods. We argue that land-use changes during these periods indicate agricultural intensification against a background of variable precipitation. In contrast, abandonment of terrace agriculture in the study area during the Late Intermediate Period suggests a possible failure to adapt to aridification coincident with a major cultural transformation.

Holocene climate-vegetation-land use interactions in the lowlands of Northern Greece

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More than 8000 years ago, the agricultural innovations that laid the foundations for modern societies spread from the Near East over Greece, the Balkans, and other Mediterranean routes. This process, named ‘Neolithisation’, involved the shift from a nomadic hunter-gatherer lifestyle to sedentary farming. Alongside the adoption of an agrarian economy, humans drastically increased their impact on the environment and the biosphere, for instance through the introduction, propagation, reduction, or extirpation of species, as well as through increased fire occurrence, erosion and eutrophication. During the initial wave of Neolithisation into Europe, past human societies had to deal with, and adapt to, environmental forcing, chiefly a major climatic shift centered around 8200 years ago.

The ERC-Synergy project EXPLO (‘EXPLOring the dynamics and causes of prehistoric land use change in the cradle of European farming’) aims at investigating key questions regarding the interaction between past human ways of life, land use, climate, and the wider environment through a unique combination of archaeological, biological, climatic and dynamic landscape modelling approaches. Within this general framework, the primary goal of our paleoecology sub-project is to gain, for periods of particular interest, continuous high-precision and high-resolution proxy records of vegetation, fire, land use, aquatic productivity, and species diversity from pollen, spores, charcoal, macrofossil, elemental, and pigment analysis. Results of these analyses will be compared with paleoclimatic reconstructions to assess societal, biosphere and geosphere responses. Our study site Limni Volvi close to the Mediterranean coast is a unique site to investigate the environmental impact of the Neolithisation on the lowlands of Northern Greece. Our results will contribute to filling the existing knowledge gap about the Holocene dynamics of mesomediterranean (partially evergreen broadleaved) vegetation in Northern Greece.

Deciphering human-environment interactions at the onset of farming in Europe with a continuous high-resolution palaeoecological record from Limni Zazari, Northern Greece

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More than 8000 years ago, agriculture was first introduced to Northern Greece from Western Asia, starting the European Neolithisation process. The establishment of early farming societies with their crops and livestock changed the natural biomes and environments of Europe forever. New land use practices had a notable impact on vegetation and fire regimes. However, these first farmers were highly dependent on their natural environment and had to adapt their practices to changes in climate and vegetation. The interplay between Neolithisation, vegetation and climate is complex and still not well understood. Continuous, high-resolution multi-proxy time series of past vegetation dynamics and fire histories are needed to understand the long-term relationships between the first Neolithic European farmers and their environment.

We analysed sediments from Limni Zazari, a small lake in Northern Greece, to study the interactions between climate, land use, fire and vegetation. We present a new continuous high-resolution vegetation, environment and fire history record spanning the Late Mesolithic and the Neolithic (ca. 10,000-5,000 cal BP), reconstructed by using pollen, spores, microscopic charcoal, XRF and Hyperspectral Imaging (HSI) scanning.

During the Mesolithic, mixed deciduous oak forests interspersed with open grassland communities covered the surroundings of Limni Zazari. Around 8,500 cal BP, a significant decline in forests occurred, together with an increase of steppe vegetation, that lasted for about 400 years. The synchronous increase in anthropogenic indicators suggests the start of agriculture in the area during this period. Early Holocene climate instability possibly facilitated the start of Neolithic farming in Northern Greece. Subsequently, after the establishment of several Neolithic settlements nearby at ~7,500 cal BP, forests experienced regular disturbances. Even though forests were resilient and recovered quickly from these disturbances, vegetation composition slowly changed.

Our study describes the interactions between vegetation, climate and the first European farming communities, with an emphasis on primeval forest response dynamics. A better understanding of the processes and mechanisms of past societal and ecosystem adaptation to climate change and disturbance may provide useful insights for a future under global change conditions.

Archaeobotanic insights into the spread of Jura lake pile dwelling wheat diversity

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Around 3900 BC, the first farmers in the Jura chose the lake shores of Chalain and Clairvaux to construct their villages in humid environments. Usually built on dry land, the houses and granaries were adapted to the waterlogged lands. The most classic case is that of villages with raised floors on stilts. According to ethnographic comparisons and approaches to social functioning, Neolithic farmers built their villages in naturally defensive positions, to shelter men and crops.

The installation of the settlements in wetlands has as an important archaeological consequence: the extraordinary preservation of organic material of plant origin such as textile, architectural timbers, wooden artefacts, textiles and vegetal remains. Furthermore, the chronological framework in wetland sites reaches an unprecedented precision, based on the dendrochronological datation of the piles and timbers. The plant macroremains are quite remarkable finds for undertaking original research. These wetland sites in the French Jura mountains thus offer archaeologists the opportunity of exploring questions on demography, social organizations and cultural practices during almost one millennium.

With hundreds of thousands of plants remains that correspond to several hundred plant species, these sites offer outstanding conditions for different issues such as the paleoenvironment, the economics and the history of anthropo-ecosystems. In the light of new studies on the origin and diffusion of agriculture, we would like to focus on the emblematic species: wheat (*Triticum spp*.), as these cultivated plants reached France, either along the river Danube or along the Mediterranean coast. The crops had to adapt to new biogeographic, climatic and cultural conditions. By focusing on wheat as a model species, it is possible to reconstruct evolutionary trajectories in response to natural factors and changes in economic and cultural practices.

Ancient Maya responses to climate change in the tropical lowlands of MesoAmerica.

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The ancient Maya of MesoAmerica continue to be of great interest because of cultural disruptions occurring in the late PreClassic (Abandonment), Classic (Hiatus) and particularly in the Terminal Classic (Collapse), when several large settlements were abandoned (ca. 800 – 1000 CE). Drought has been implicated as a potential driver of these periods of change, although a range of other causes have been suggested, including environmental degradation caused by human activity. The timing and scale of change was, however, highly variable suggesting differential resilience of both natural and human systems.
We combine elemental, geochemical, palynological and charcoal data from the New River Lagoon and Ambergris Caye (Belize) and Laguna Esmeralda (Mexico) to track changes in climate, vegetation cover, key cultivated crops (e.g. *Zea mays)* and fire histories with available evidence from the archaeological record to explore the interactions between humans and climate.
The New River Lagoon (NRL) is a large open system, with the important Maya settlement of Lamanai on its western shore. There is limited evidence for drought in the Terminal Classic and Lamanai was not abandoned. The Ambergris Caye site lies close to the PostClassic settlement of Basil Jones, but records much longer human disturbance across the island. Laguna Esmeralda lies in an area with no evidence for large Maya settlements. Drier conditions seem to be recorded at the time of the Abandonment, Hiatus and Collapse and early cultivation apparently had little impact on forest cover. Evidence for climate change, the timing of maximum human impact and economic strategies varies across these sites, suggesting variations in the resilience of both natural and human systems.
Comparison with other key climate records such as those from Yok Balam and Macal Chasm provides further insights into interactions between people, climate, and their environment over the late Holocene.

Collapse of the pre-Columbian Monumental Mound Culture in the Bolivian Amazon

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The Llanos de Mojos (LM) of Amazonian Bolivia is a mosaic of tropical rainforests and seasonally-flooded savannas, home to the Monumental Mound Culture (MMC) – perhaps the most complex pre-Columbian (pre-AD1492) society to have developed in Amazonia. In a region which is today sparsely populated and used mainly for cattle ranching, the MMC built a complex network of artificial earthworks, comprising > 150 monumental habitation mounds (HM) interconnected by canals and causeways. Little archaeological and palaeoecological research has yet been undertaken, but it points to a densely populated, stratified society, based upon intensive maize agriculture. This project addresses a fundamental question: ‘When and why did the MMC collapse?’

Emerging archaeological evidence suggests that the MMC disappeared ca. AD1400, ~150 years before European arrival, challenging the paradigm of post-Contact collapse. However, whether this chronology of site abandonment is representative of the MMC is unknown. The limited palaeoecological research shows temporal correlation between archaeological earth-work occupation and charcoal peaks in sediment cores of neighbouring lakes and bogs. The latter leads us to infer, that changes in charcoal abundance serve as a proxy for changes in human population density.

We use a palaeoecological approach to determine the spatiotemporal pattern of abandonment of the HM across the MMC region. We present high-resolution fossil charcoal and cultigen pollen records, from cores of 8 lakes and palaeo-river channels, with Bayesian age-depth models spanning the past 1-2 millennia. The palaeo-channels, adjacent to the HM, capture land-use change on individual HM, while lake records, capture land use at coarser-grained spatial scales.

Based on the premise that long-term declines in charcoal signify site abandonment, we test the following hypotheses: the collapse of the MMC preceded (H1) *versus* post-dated (H2) European arrival; collapse of the MMC was sudden and simultaneous across the region (H3) *versus* spatially heterogeneous and time-transgressive (H4).

Analyses of these fossil records are ongoing. However, preliminary data from 3 sites (Lagunas San Jose, Peroto, Loma Suarez) is consistent with H1. Once our analyses are complete, we will cross-correlate our charcoal and cultigen pollen data with speleothem records from the region to examine the possibility of climate-driven collapse.

From microscopic biodiversity to macroscopic similarities between past and present environmental dynamics: the case study of the Terramara S. Rosa di Poviglio (N Italy)

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Changes in plant species richness and composition have been triggered by the interaction's dynamics between human societies, ecosystems, and climate. The environment and human populations influence each other: changes in the cultural landscape occur in response to different climatic conditions, and the development of societies modulates ecosystems. In such context, Palynology, being a trans- and inter-disciplinary science, can explore biodiversity changes in a long-term perspective with the aim of obtaining functional answers to interpret current environmental and social dynamics.

Here, we present a palynological investigation carried out in the Po Plain, the main floodplain of northern Italy, focusing on the interaction between human–water systems during the Holocene. Three terrestrial cores were collected in the framework of the SUCCESSO-TERRA Project (PRIN-20158KBLNB) in the area surrounding the Terramara S. Rosa di Poviglio, a Middle Bronze Age settlement belonging to the Terramare culture, which has been investigated for almost 40 years.

Pollen spectra describe a long-term picture of large-scale vegetation changes as a dual result of climatic oscillations and human overprints. We noticed a shift towards a permanent and extensive impact on biodiversity during the Middle Bronze Age, from the establishment of the Terramara culture until its societal crisis. The latter was triggered by extensive and intensive agricultural and livestock overgrazing. Our data are further evidence that the prolonged and intense exploitation of a territory transformed the natural environment into a cultural landscape with the development of new conditions untenable for civilisations without taking subsistence adaptations.

A multiproxy record of human and climatic impacts on disturbance and vegetation in the Southern Rocky Mountains, USA

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Human populations have a long history of ecological impacts on forests in the mountains of the Southwestern United States. Networks of tree-ring archives demonstrate shifts in regional fire regimes associated with Native American land use followed by Spanish and American colonization. However, tree-ring records fade before ca. 1400 AD, which limits understanding of long-term interactions among humans, climate, disturbance, and vegetation in this fire-prone region. We are addressing this limitation with a multi-proxy record of environmental change from Santa Fe Lake, New Mexico (3532 m a.s.l.), the southernmost lake in the Rocky Mountains. We are reconstructing vegetation dynamics with pollen analysis, fire histories with sedimentary charcoal, paleohydrology with diatom analysis, and the presence of humans in the watershed with fecal sterols. Sediment began accumulating at Santa Fe Lake ca. 13,755 cal yr BP. An abundance of pollen types transported from lower elevations, (e.g., *Artemisia* up to 50%) indicate an open landscape existed near the lake at this time. Increasing *Picea* pollen after 12,000 cal yr BP record the regional expansion of subalpine forests. Stomates and needles of *Picea* and *Abies* document the arrival of the upper treeline at the lake by 10,000 cal yr BP. *Pinus* also increases at this time, probably due to expansion by *Pinus ponderosa* at lower elevations. Increasing *Abies* and *Pinus aristata*-type pollen after 7000 cal yr BP may indicate an expansion of the upper treeline ecotone above the lake. Preliminary data suggest that agriculture became established in the region after 1200 AD (750 cal yr BP), when maize pollen first appears in the record. The largest peak in microscopic charcoal accumulation also occurs at this time, which suggests an increase in regional burning, perhaps related to the establishment of permanent Puebloan settlements. We are further exploring these long-term human impacts using fecal sterols and charcoal analysis.

Session 28: Timing and structure of freshwater ecosystem response to external forcing: evidence from high-resolution multi-proxy lake and peat bog records

Climate synchronicity in Tasmanian terrestrial and aquatic ecosystem over the Holocene

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PowerPoint Presentation

Climate is the most important driver of aquatic ecosystem change, effecting changes to nutrient status, productivity, and ecosystem health and function. Aquatic ecosystems are affected by two climatic forces *energy* and *mass*. *Energy* encompasses the direct climate influences of heat, wind, and irradiance. Whereas *mass* fluxes are the indirect climate influences of *energy* on the terrestrial environment, catchment, and aquatic ecosystem through avenues of changing vegetation, soil development, and catchment dynamics that alter aquatic ecosystems. While there is a greater understanding of climate impacts on freshwater systems, and a growing understanding of the complex indirect relationships climate has on these environments; the patterns related to *energy* and *mass* on longer timescales and larger spatial scales are not particularly well-known. Tasmanian freshwater systems show tight coupling to the terrestrial environment with changing climate over the Holocene. Climate related shifts in fire regimes, vegetation, and catchment dynamics indirectly drive aquatic ecosystem change including changes in species assemblage, pH, nutrient status, and light availability. While there is evidence of both *energy* and *mass* climate influences on the terrestrial and aquatic ecosystem of Tasmania, the timing (synchronicity) and consistency (coherence) in these responses have not been evaluated on a regional scale. Using five multiproxy lake records from western Tasmania of pollen, charcoal, aquatic remains, and generalise additive modelling we aim to answer the following questions:

Q1- Are Tasmanian terrestrial and aquatic environments responding synchronously or asynchronously to Holocene climate?

Q2- Do terrestrial and aquatic ecosystems show consistent patterns (coherence) of direct and indirect responses to climate over the Holocene?

Preliminary findings show synchronicity between rainforest and aquatic ecosystems changes at ca. 3.5 ka, with the exception of an early response at one site (Paddy's Lake) at ca. 6 ka. During the early Holocene, sites are responding to *mass*, but with onset of drying sites have a mixed *mass* and *energy* response due to differing biogeography. Synchronicity and coherence is unexpected in sites driven my *mass* where more variability in anticipated, however, there is evidence of synchronicity and coherence in the terrestrial and aquatic ecosystems across western Tasmania.

A palaeoecological evaluation of Typha as a potential tool for wetland management in New Zealand. Part 1: ecological perspectives

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Palaeoecology can inform a process-based understanding of ecosystem function and resilience, that can in turn help guide restoration strategies. The potential for this 'past-present-future' approach is especially high in the case of wetlands, which can provide a range of critical 'ecosystem services' but have been vastly depleted in recent decades. Here we investigate the ecological roles played by the wetland plant *Typha orientalis* (raupō) in New Zealand prehistory and consider the important implications for future freshwater wetland management. In the context of recent pervasive wetland degradation throughout New Zealand, this iconic yet enigmatic plant can be viewed as an invasive threat or as a valuable ecological and economic resource and a natural, indigenous agent for bioremediation. As this New Zealand species shares the same intrinsic ecological and morphological attributes of the ~40 species or hybrids of *Typha* that span most of the planet, this work may find resonance in many other regions as well.

Our preliminary investigation presented here reconstructs the history of *Typha* over the past ~1000 years, based on interrogation of 91 new pollen records along with a range of ecosystem health indicators generated from lake sites across New Zealand. These new records build upon previous work showing that *Typha* consistently responded to disturbance, accentuated by human activity, but in different ways. At almost every site (82%) where *Typha* is present naturally, its expansion is promoted to varying extents during - and presumably because of - periods of human activity and in particular forest clearance and associated sediment and nutrient flux. These multiple patterns of response over time point to a range of hydrological, trophic and cultural scenarios that are conducive for *Typha* expansion. Intriguingly, independent proxies point to stable or even improved water quality conditions during the *Typha* expansion phase at some sites, raising important questions about its potential role in mitigating the ecological impacts of disturbance. In a separate presentation at this congress we show that *Typha* expansion also provided new opportunities for its use as a valuable food and material resource, prompting further questions as to the extent it was deliberately managed by prehistoric populations.

Identifying the Homerian Climate anomaly through high resolution analysis of annually laminated sediments from Holzmaar, Germany

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Paleoclimatic reconstruction helps to place contemporary climate change into perspective of natural climatic variability and thus increases our understanding of the climate system. Previous studies have identified cold and wet periods for the past millennia across Europe. Yet and due to the lack of high temporal resolution datasets, the climatic mechanisms controlling these events remain unclear. Here, environmental archives with annually laminated (varved) sediments come into play, since they permit a calendar-year chronology and allow calculation of precise sediment accumulation-rates. One of the most widely used biological proxy for lake records are diatom assemblages, as their species composition is related to climate variability and anthropogenic impact. As an overview, we performed multiproxy analyses of a sediment record from Holzmaar (West-Eifel Volcanic Field, Germany) that covered the last 16,000 years. In addition to diatom assemblages, we analysed physical (magnetic susceptibility) and geochemical proxies (biogenic silica, elemental composition) to assess the main trends of paleoenvironmental change with a centennial resolution for the 14 m-long composite record. In this contribution, we focus on the Homerian Climate Anomaly (ca. 2750 cal. BP) with high decadal temporal resolution. This short and wet event not only coincides with a period of low solar radiation, but also with the most pronounced biostratigraphic shift from the Subboreal to the Subatlantic and the transition from late Bronze Age to early Iron Age settlements. We aim to provide insights into diatom biodiversity patterns during this period. With the support of other proxies this helps to disentangle climatic variations for this transition. For example, a distinct increase in windiness is documented by diatom blooms of *Stephanodiscus minutulus*. We expect our contribution to be the starting point for similar analyses of sediments from different other varved Central European lakes in search of the Homerian Climate Anomaly. The overarching aim is to correlate this event in space and time and eventually establish a regional assessment of this climate anomaly.

Evidence for natural lake anoxia events during abrupt climate change in the last 130 ka in Eurasia

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Nutrient excess in lakes causes an increase in aquatic primary productivity, often leading to the establishment of hypolimnetic anoxia. Under these anoxic conditions, redox-sensitive elements such as iron, manganese and phosphorous may be redissolved from the sediment and released into the lake water. These elements increase primary productivity, prolonging lake anoxia and establishing positive chemical feedback mechanisms.

Studies have shown that (natural) eutrophication leading to the establishment of anoxia can be found even in pre-anthropogenic times. However, links between climate change, eutrophication, and the development of hypolimnetic anoxia are still poorly understood. Furthermore, it is unknown whether such successions of anoxic events were entirely or only partly reversible and how long it took for natural lake ecosystems to recover. Thus, we aim to compare (i) the reaction of morphometrically similar lakes to the same climatic perturbation, e.g., Dansgaard-Oeschger Events (DOE), and (ii) the reaction of individual lakes to a sequence of similar climatic perturbations. We investigate high-resolution lake sedimentary records from volcanic lakes in the Eifel, Germany, covering the last 130 ka and compare them to Swiss, Italian, and Chinese lakes.

Using a multi-proxy approach, we apply scanning XRF to detect elemental composition and hyperspectral-imaging pigment detection to estimate primary productivity and hypolimnetic anoxia. Additionally, we use HPLC for qualitative pigment determination to trace shifts in the community of primary producers. Furthermore, we use sequential extraction of redox-sensitive elements (Fe, Mn, P) to trace evidence of anoxia, related redissolution processes and internal cycling of nutrients.

Preliminary results suggest that, because of rapid climate warming, the succession starts with excessive nutrient delivery from the catchment, causing an increase in primary productivity composed of green algae. When anoxia develops, anoxic phototrophic green and purple sulphur bacteria partially replace the green algae. Additionally, the redox-sensitive and reactive P, Fe, and Mn fractions decrease in the sediment, indicating redissolution and internal P recycling. Thus, the internally fertilized lake continues in a high productivity mode.

Our results establish a link between climate change and biogeochemical responses of lakes, which are essential for future projections, e.g., lake ecosystem protection strategies or water resource management plans.

Understanding the role of palaeoclimatic drivers on cyanobacteria bloom development in shallow lakes

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Harmful cyanobacterial algal blooms (CyanoHABs) have garnered increased public and scientific interest due to the potentially devastating impacts of their toxic secondary metabolites on biota. This has created significant impetus to understand the spatial and temporal drivers associated with their development. While anthropogenic nutrient enrichment and climate-related processes are recognised as important controls on CyanoHABs in modern lake environments, few studies have explored the mechanistic links between specific climatological stressors (e.g. storm events) and past episodes of CyanoHAB development.

This multi-proxy palaeolimnological study is examining the relationships between past toxic algal bloom events, climatological controls (especially historic storms) and catchment-related disturbances in recent (ca. last 500 yr), shallow lake sediment records from New Brunswick, Canada, a maritime region which has seen an increased frequency of lake CyanoHABS in response to land-use change and historic storms.

Palaeo-climatological shifts were investigated in three dated sediment cores using End-member Mixing Analysis (EMMA) of grain-size data, which aids in the determination of depositional pathways associated with hydrological processes (e.g. heavy precipitation) and Itrax X-Ray Fluorescence (XRF), which is useful for detecting palaeo-precipitation and palaeotempest signals. Cyanobacterial responses were inferred from fossil sedimentary pigments and microcystin congeners (cyanobacteria-specific metabolites that preserve in sediments). Ongoing stable isotope analyses ($\delta^{13}C$; $\delta^{15}N$) will further aid in understanding lake productivity shifts and changes in lake sediment provenance.

Our results show that toxigenic metabolites increased by several orders of magnitude in the uppermost (<5 cm) core sediments from all the study lakes. This coincides with fossil pigment shifts, increases in sedimentary phosphorus, and increases in XRF-derived storm air mass signals. In one site (Harvey Lake) notable changes in the upper 2 cm of the record are linked to a major 2014 storm which triggered a significant CyanoHAB event. In another lake, four staggered zones of microcystins may indicate periodic phases of toxigenic cyanobacteria throughout the 0.35 m record.

The mosaic of palaeolimnological proxies being applied in this study will be critical for untangling the complex ecological, sedimentological and geochemical responses of these CyanoHAB-impacted lakes to climate-related stressors. This, in turn, will be integral for understanding their resilience to future change.

Aquatic community response to a century of environmental change and human impacts in Searsville Reservoir, CA

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Aquatic invertebrates are critical components of lake ecosystems. They are foundational to lacustrine food webs and often act as bioindicators for aquatic health. Microcrustaceans such as ostracods and cladocerans are particularly sensitive to changes in lake conditions including vegetation shifts, water depth fluctuations, and pollution inputs. Microcrustacean remains preserved in sedimentary records therefore have the potential to record environmental change and human impacts over time.

We analyzed the composition and abundance of freshwater microcrustaceans in a high-resolution sediment core from Searsville Reservoir (Woodside, California, USA) to track environmental change, including human impacts, over the last ~130 years. We paired this with a pollen analysis to examine concurrent shifts in algae and aquatic vegetation, providing context for microcrustacean community change. Searsville's high sedimentation rate – 12 cm/yr on average – provides a rare opportunity to explore community assembly at the ~yearly level following the creation of this anthropogenic system. Sediment samples were collected from Searsville core JRBP2018-VC01A for the analysis of ostracod valves and cladoceran ephippia as well as pollen, spores, and non-pollen palynomorphs. Representative specimens of each ostracod taxon were photographed using a scanning electron microscope (SEM) and the remaining microcrustaceans were identified under a compound microscope. We then used stratigraphically constrained hierarchical cluster analysis (CONISS) to assess whether there were significant shifts in microcrustacean community composition across the core.

CONISS revealed multiple shifts in the microcrustacean record, which we interpreted with the aid of the pollen record and detailed historical documentation. Increases in microcrustacean relative abundances were correlated positively with wetland rooted aquatics and negatively with algae. In addition, historical records of pesticide inputs to Searsville correspond with dramatic shifts in the microcrustacean community. Together, this multiproxy approach records the stabilization of the reservoir sediments, the proliferation of rooted aquatics, the shallowing of the lake over time, and especially the heavy use of herbicides in the 1950s.

This work adds an important microcrustacean record to California and contributes to the environmental record of this watershed. Microcrustaceans play an important role as tracers of anthropogenic pollutants in the Anthropocene.

Lake recovery pathways: testing ecosystem resilience from historic lake settlement impacts

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Cultural eutrophication is one of the most widespread pressures on lake systems, with profound impacts on ecological structure, function and overall biodiversity. Probably the first impacts to lakes worldwide occurred as people settled around lake shores, and here we focus on specific lake dwelling sites, both artificially built and natural, called crannogs. Our studies concentrate on Scottish and Irish crannogs, constructed in the Iron Age and Medieval periods, which provide point source inputs into relatively small lakes, typically resulting in cultural eutrophication. These impacts can be quite specific spatially, and we use cores from near the crannogs, in addition to open water (lake central) cores to consider local vs lake wide impacts. The lake sediment cores have been well dated, and analysed for a wide range of proxies, including aquatic subfossil indicators, pollen, sedimentary ancient DNA (sedaDNA), and geochemical analyses. We collate these datasets to assess aquatic ecosystem responses (diatoms, chironomids, macrophytes) against a range of drivers, including land use change, animal abundance and associated processes, and other catchment changes.

While we, broadly, have a good knowledge of the mechanisms by which freshwater lakes can collapse to a degraded state, we have relatively little understanding of the nature and pace of their recovery to a resilient state. We measure resilience in terms of structural change (as opposed to frequency analyses of time series) through a suite of recently developed metrics, and here we use our datasets to test these new metrics across lake recovery from crannog impacts. Our data show that as the crannogs are abandoned, and point source inputs reduced, the lakes typically start to recover. We will use our data to consider whether the lakes respond through different recovery pathways, and/or whether they only achieve partial recovery against the backdrop of continued external, often diffuse, pressures. Furthermore, we will consider how different trophic levels respond to recovery as the ecosystem networks readjust to hysteresis on a timescale of decades to centuries.

Tracking historical human disturbances on remote islands using a multiproxy approach: Lake Ginjal record (Terceira Island, Azores)

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The discovery and occupation of remote oceanic islands drastically modified their ecosystems, and the Azores was no exception. One of the first impacts of human arrival was changes in vegetation due to land clearance practices, an increase in soil erosion, introduction of exotic species, and homogenization of these unique ecosystems. Here, we provide the first environmental reconstruction based on multiproxy analysis (pollen, diatoms, cladocera, chironomids, charcoal, and organic matter) from Terceira Island spanning the last 650 years. We distinguished four main phases in Lake Ginjal: ca 1420-1500 CE (PI), 1500-1650 CE (PII), 1650-1950 CE (PIII), and 1950-modern (PIV). Phase I coincides with the official dates of Portuguese discovery and subsequent settlement of the archipelago. The absence of native forest species, the very low relative abundances of trees and shrubs throughout the record, and the dominance (> 90 %) of herbaceous plant pollen, clearly suggest a firmly already established open grassland. Furthermore, the continuous occurrence of coprophilous dung fungal spores and macro-charcoal particles and the presence of *Cerealia* sp. also support this point. This pressure on the terrestrial environment was also exerted on the lake. Abundance peaks in aerophilic diatoms (e.g., *Pinnularia borealis)*, plus the presence of chironomids associated with low oxygen requirements (e.g., *Chironomus* spp.), indicate a high lake trophic state. From ca. 1500 CE all proxy-based records changed significantly, coinciding with a marked growth in the human population on Terceira island. The sharp rise in the dominance of macrophyte-associated taxa, such as *Tabellaria flocculosa*, and lower TOC/TN values indicate a rise in lake trophic state. Phase III starts with a significant decrease in Cladocera and chironomids influx and an expansion of eutrophic diatoms such as *Fragilaria tenera*. This pattern is similar and coeval to those observed in other Azorean lakes, with the introduction of exotic fishes, which intensify internal nutrient release in the lake, leading to an increase in eutrophication. The last phase is characterized by changes in biological assemblages from more open-water (*F. tenera*) to macrophyte-associated taxa (*Alonella nana*), suggesting a shallow lake level trend due to near-complete sedimentary infilling and the subsequent development of a paludification process.

Session 29: Escaping the trap: frontiers of trapped charge dating

Finding Quaternary Seismogenic Activity along the Eastern Periadriatic Fault System: Dating of Fault Gouges using Trapped Charge Methods

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The Periadriatic Fault System (PAF) is among the most important and largest post-collisional structures of the Alps; it accommodated between 150-300 km of right-lateral strike-slip motion between the European and Adriatic plates from about 35 until 15 Ma. Recent GPS data suggest the Eastern Alps are still accommodating Adria-Europe convergence. However, according to instrumental and historical seismicity, seismotectonic deformation is mostly concentrated in the adjacent Southern Alps. In this contribution, we aim to show which segments accommodated seismotectonic deformation during the Quaternary by applying Electron Spin Resonance (ESR) and Optically Stimulated Luminescence (OSL) dating to fault gouges produced by the fault system. The method is especially useful for dating shear heating during earthquake activity at near-surface conditions due to its dating range (a few decades to ~1 Ma) and low closure temperature (below 100°C). For ESR, we measure the signals from the Al center in quartz following the single aliquot additive (SAAD) and single aliquot regenerative (SAR) protocols, focusing on the 100-150 µm grain size fraction. For OSL, we use the SAR protocol and measure the infrared stimulated luminescence (IRSL) signals at 50°C and 225°C on potassium feldspar aliquots of the 100-150 µm grain size fraction. Our ESR results indicate the PAF system accommodated seismotectonic deformation during the last 1 Ma, while the minimum ages obtained via OSL suggest that the events are not likely younger than 0.4 Ma.

Luminescence chronology and thermometry studies of plant opal phytoliths

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In this work we have been investigating luminescence properties of plant opal phytoliths to assess their suitability for determination of age and thermometric information from soil and sediment sequences. Opal phytoliths form when monosilicic acid from soil-waters is taken up by plants and altered to silica, producing intra- or extra- cellular structures giving grasses and stems their strength. Opal phytoliths are usually considered non-crystalline and referred to as mineraloid structures, with ~4-9% water, <5% other elements, and specific gravity ranging from ~1.5-2.3. They are known to be resistant to degradation and preserved in soil or sediment after decomposition of organic matter. Earlier work examined a <2.37 g/cm^3 density fraction in parallel with quartz grains from samples from fluvial terraces and soil pits on Konza Prairie Biological Station native tall grass prairie a few km from Kansas State University. We observed similar luminescence characteristics from the phytolith fractions to quartz, with bright blue OSL signals and good single-aliquot regenerative-dose characteristics. In two hours the OSL signal is ~90% bleached by white light, whereas red fluorescence lab lighting has a negligible effect over the same exposure time. TL data suggested the presence of feldspatic-like minerals or perhaps thermal degradation of the phytoliths during measurement; the phytolith fractions were also stimulated by $IRSL_{50}$ perhaps also indicating contaminant minerals. SEM analyses identify what appear to be weathered silica grains, but also highly weathered, pitted concretions with silicate-like structures from element mapping but actual mineral identification is unclear.

Recently we have begun analyzing samples collected from a suite of stratified paleosols from the mid-continent stream type-site of Claussen, Mill Creek, Wabaunsee County, Kansas. This site has documented phytolith examples and a radiocarbon framework. We are continuing characterization studies, incorporating screening of prepared fractions with SEM and $IRSL_{50}$ evaluation, and pulsed time domain analysis measurements are being explored.

We think luminescence from opal phytoliths shows great promise as an alternative target to quartz or feldspar, but moreover as a sensitive recorder of climatic change or fire exposure on plant communities. This presentation will review earlier work and discuss most recent findings from the Claussen site.

Detection of ancient heating in archaeological sediments: Not as simple as it looks!

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A number of single-grain dating studies of archaeological sediments have documented samples where the luminescence properties differ from those of the surrounding sediments. This phenomenon has been attributed to heating in antiquity. Similarly, single-grain sensitivity distributions from experimentally heated quartzes have been used to infer ancient heating of geological materials, thereby allowing them to be dated by luminescence techniques. However, although firing is a probable explanation of otherwise anomalous differences between the luminescence properties of adjacent samples/grains, relatively few studies have measured the effect of firing upon individual mineral grains. A fuller understanding of thermally induced changes in luminescence properties, particularly the sensitivity of quartz, could allow a) detection of hearths or burning features in archaeological sediments and b) identification of post-depositional resetting of luminescence signals by hearths constructed in overlying sediments.

In this study we present luminescence data from samples obtained during an experimental archaeology field season conducted near Blombos Cave, South Africa, by researchers from the SapienCE Centre of Excellence. Fires were constructed and burned upon a modern sand substrate obtained from coastal dunes near Blombos Cave. Temperature was continuously recorded at the sand/fire interface, and at 5 and 10 cm depth, yielding samples with a well-documented firing history. Burn times ranged from 1 to 10 days. The natural single-grain sensitivity distributions and abbreviated thermal activation characteristics (observation before and after a single controlled episode of heating) were measured for quartz extracted from fourteen samples with known firing histories. The effects of firing can be detected in both datasets, but samples with similar firing histories yielded different sensitivity distributions. Exposure in a UVACube 400 solar simulator also modified sample sensitivity distributions. This observation suggests that firing is best detected when the sample has not been exposed to sunlight, even if there is no intention to measure the sample's equivalent dose. The implications of our observations for identifying ancient heating in data obtained during routine equivalent dose measurements will be discussed.

Single-grain luminescence signal from modern fluvial feldspar sediments to investigate fluvial transport

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Luminescence in single-grain was developed to date sand deposits in which grains were heterogeneously bleach by sunlight before deposition, which is common in fluvial context.

In this study, we measured the single-grain post-infrared luminescence (SG-pIRIR) signal from modern flood-plain deposit from the Rakaia and the Waimakariri braided rivers running in the Canterbury Plains in the South Island of New Zealand. As suggested in publications from the last decade (McGuire and Rhodes, 2015; Gray et al.,2018; Sawakuchi et al., 2018), we used luminescence signal to quantify transport processes and transient storage of particles in floodplains in those rivers. We found for both rivers that the percentage of saturated grains and the mean D_e of the D_e distribution follow exponential decays with distance along the river. On the opposite, the quantity of well-bleached grains of the D_e

distribution increase exponentially towards downstream.

To get information on transport and storage from those trends, we developed a numerical model that simulate the successive displacement and D_e evolution of grains along a river. The code includes three main processes that repeat until each grain reach the river outlet: (1) displacement of a distance set with an exponential probability density function (PDF); (2) temporary storage for a period R_t between two displacements in the floodplain, set with a PDF that follows a Pareto law (exponent=-2). During R_t, D_e can increase proportionally to the dose rate; (3) bleaching of grains during displacement (fluvial transport) or storage (if exposed at the surface of the floodplain during Rt) according to a probability P_{Bl}. To first order, this simple model simulates well natural observations from Canterbury Plains rivers. This very simple transport model allows to decipher SG-pIRIR data and to estimate the mean transport length between 2 and 10 km and mean resting time between 20 and 150 years of sand-sized fluvial particles. Future works should consider testing these tools on other tectono-climatic or different flow styles contexts.

Using infra-red stimulated luminescence to understand sediment transport during flood events

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Understanding sediment transport dynamics provides key insight into frequency and magnitude of flood events in fluvial systems. Accurate prediction of high flow events has important implications for disaster preparedness, transmission of water-borne diseases, and our understanding of landscape evolution. Multiple elevated temperature infra-red stimulated luminescence (MET-IRSL) has great potential to provide detailed information on the movement of sediment grains through time and space. MET-IRSL stimulates grains using infra-red at a series of elevated temperatures to access multiple charge populations with different bleaching behaviours. Past light exposure and storage times can be determined by the relative difference between signals of a single grain or aliquot. The distribution of light exposure and storage through time can constrain the frequency and magnitude of high flow events.

We present field data from Scotland, California and Malawi, combined with a numerical modelling approach to understanding fluvial sediment transport and flow dynamics using MET-IRSL. A combination of single grain and multiple grain techniques are used to determine downriver changes in luminescence characteristics of grains, which reflect alternating high and low energy conditions. Downriver changes in luminescence are simulated using optimised bleaching and growth functions, to forward model the characteristic transport and flow regimes for these systems. This represents one of a set of tools we are developing to understand risk of water-borne disease outbreak associated with sediment transport during high flow or flood events in Malawi.

Coupling dosimetric methods (luminescence and ESR) with hydrosedimentary connectivity to unravel source-to-sink dynamics in the Strengbach catchment (Eastern France)

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Sediment routing systems in fluvial catchments are primarily governed by intertwined climatic, tectonic and man-induced drivers at the centennial/millennial timescales. Among the various geomorphicical and geochemical approaches developed to trace sediment dynamics, the scientific community has recently explored the potential of (palaeo-)dosimetric methods, which are extensively used to date e.g. Quaternary alluvial environments. Recently, optically Stimulated luminescence (OSL) and Electron Spin Resonance (ESR) signals have been successfully transposed to decipher sediment provenance and transport in fluvial catchments. In parallel, the index of connectivity has been growingly used to quantitatively assess catchment-scale hydrosedimentary connectivity over the last decade.

Against this framework, the French ANR QUARTZ research project aims at using quartz grains as an ubiquitous marker of sedimentary dynamics to understand (i) how each quartz grain holds a source-specific signature, and (ii) how this signature evolves along sediment routing systems. This study specifically focuses on the second aim. Longitudinal measurements of OSL and ESR signals from modern river borne sediments are performed together with the assessment of the catchment-scale index of connectivity. It is argued here that coupling both information can help to quantitatively unravel source-to-sink sedimentary dynamics. More precisely, the longitudinal evolution of ESR and OSL residual doses in quartz sediments is reconstructed. Whilst a downstream decrease of residual doses is expected owing to increasing duration to light exposure with increasing transport distance, sediment inputs from tributaries can blur this signal. Here, this relation between bleaching evolution of quartz and sediments inputs is investigated via the index of connectivity.

A first campaign was performed in the Strengbach catchment in the Vosges Mountains (Eastern France) as it represents an ideal natural laboratory. Firstly, the geochemical composition of the source materials has been studied for more than thirty years. Secondly, it contains various quartz-bearing formations, i.e. plutonic, metamorphic and sedimentary. Finally, it displays a simple geomorphic configuration with (i) well-identified sources in the Vosges Mountains, (ii) a deeply-incised main valley with absence of significant intermediate storage (e.g. no terrace system) and (iii) a clear, single sink (Upper Rhine Graben). This allows representative computation of the index of connectivity (or dysconnectivity).

Quartz ESR Thermochronometry to constrain neotectonic movements on the Central and Eastern Alps

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Low temperature thermochronology is a useful tool to reconstruct the tectonic deformation of the upper crust. It is a suitable tool to investigate deformation associated with cooling and exhumation of the lower crust in orogenic settings. Quartz is the most common mineral in the crust, and it occurs in magmatic as well as sedimentary and metamorphic rocks. The potential of quartz electron spin resonance (ESR) as a radiation dosimeter has been well documented, and many studies applied the method to date sediments and heated rocks (e.g. tephra). In this study we apply quartz ESR dating as an ultralow-temperature thermochronometer, characterized by a closure temperature of 30° - 90°, and dating range of 10^3-10^7 years. We show the first results of ESR thermochronometry on quartz applied to rocks from crustal scale faults in the Eastern Alps. Here, the lower crust has been tectonically exhumed associated with exhumation of the Tauern Window. Several low-temperature thermochronological data are available from this area, such as fission tracks or U-Th/He data on zircon and apatite. Results of the first ESR measurements of 15 samples crossing the Brenner and Salzachtal faults (northern and western border of the Tauern Window) show that the ESR ages of quartz get younger toward the central part of the Tauern Window, in accordance with fission track and (U-Th)/He ages. Moreover, we are able to show that the ESR ages fit with the normal tectonic movement of the Brenner Fault. These first results are promising to establish ESR as an ultra-low thermochronometer using the most common mineral in the crustal rocks, quartz.

Session 30: A multiscale geoarchaeological approach for the interpretation of palaeo-landscapes and human activities

Finding Suitable Grounds: Multiscale geoarchaeological tracing of the start of crop cultivation in submerged and buried landscapes of the Netherlands.

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We present a new project ("Finding Suitable Grounds") that focusses on buried and submerged Mesolithic and Neolithic landscapes in the Netherlands. The exceptional conservation of the natural surfaces from the age of the "neolithization window (6000 – 4000 cal. Yr. BC)" provides unequalled opportunities for studying the agricultural transition, and its impact on the natural environment. We will investigate in detail where, how and when humans in the Dutch lowlands first managed to clear suitable grounds and started crop cultivation.
We use newly collected and digitally archived (legacy) sedimentary, palynological and archaeological surveying data as well as new geophysical survey data to identify and target the most suitable areas for crop cultivation in the drowned and submerged landscapes. On new core samples we will use an approach that combines soil micromorphology, 14C dating and multi-proxy palaeobotanical analyses. These will reveal in minute detail how the various landscape niches were used by hunter-gatherers and how this use changed due to the adoption of crop cultivation, as well as by the rising sea level.
The introduction of farming (including crop cultivation) was a major development in the history of human society, abandoning the hunter-gatherer mobile life styles for more settled ones. Discussions on the mode and speed of this change have been a major topic among archaeologists and anthropologists. The 'neolithization debate' between those who advocate a quick adoption, and those who regard the process as one of gradual inclusion is still not resolved.
Geoarchaeology has until now played a (too) limited role in this debate. This is unfortunate, as geoarchaeological data, proxies and research methods at a range of different scales - from region to microscope - are essential for understanding the potential for crop cultivation of different landscape features and for their spatial delineation. Moreover, they make it possible to identify past cultivation practices and for contextualizing and focusing multi-proxy palaeobotanical studies into human subsistence and ecological impact.

Multi-disciplinary geophysical and geoarchaeological investigations indicate a Mid-Holocene environmental shift at Neolithic wetland site of Pestenacker (South Germany)

Ms. Anne Köhler [1]***, Dr. Ulrike Werban*** [2]***, Mr. Marco Pohle*** [2]***, Mr. Johannes Rabiger-Voellmer*** [3]***, Dr. Birgit Schneider*** [1]***, Mrs. Anneli Wanger-O'Neill*** [4]***, Ms. Stefanie Berg*** [4]***, Prof. Peter Dietrich*** [2]***, Prof. Christoph Zielhofer*** [1]

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Reconstructing past human and environmental interaction is a substantial component of understanding 'great transitions' within these complex systems and their interdependencies.

We focus on the reconstruction of the Late Neolithic wetland occupation history at Pestenacker, an UNESCO world heritage site in the northern Alpine forelands of central Europe. We aim to recover and understand potential interactions between supra-regional climate forcing and local socio-ecological response mechanisms. In this context, we used larger scale geophysical prospection methods (Electromagnetic Induction, Electrical Resistivity Tomography and Direct Push sensing with two different probes) in combination with small-scale driving core drillings and results of archaeological excavations to create a high-resolution stratigraphic record of the valley. In addition, we compare the stratigraphical data with the dendroarchaeological and radiocarbon data sets to reconstruct the human environmental interactions at the study site during the Holocene.

Changing climatic patterns induced a shift of hydrosedimentary conditions around the prehistoric settlement site of Pestenacker during the Mid-Holocene. Decreased temperatures and increased precipitation, resulted in the formation of a stream course and therefore a drainage of the fen at the valley floor. This probably indicates a regional hydrological tipping point and subsequently favours conditions for valley floor settlement during the Late Neolithics.

Multi-scale formation processes of open-air Middle Paleolithic sites in the arid Negev desert, Israel – A conceptual model

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Open-air anthropogenic accumulations of material cultural residues are often perceived as partial, distorted, and potentially time-averaged archaeological records, where it is difficult to distinguish underlying anthropogenic vs. geogenic factors and the temporal span of formation processes, and how these affected the integrity of archaeological records. In this study we analyze the depositional histories of three Middle Paleolithic archaeological open-air sites in the arid Negev desert of Israel, by combining archaeological and geomorphological methods to create a conceptual model of multi-scale effects on the archaeological remains. We rely on the long research history in archaeology and geomorphology in the Negev desert and show that integration of archaeological and geomorphological methodologies provides nuanced insights to our understanding of the archaeological record. Further, when applying a multi-scale analysis of the regional and local processes that affected each site, the links established between regional and local geomorphic processes and lithic taphonomy allow back-tracking environmental processes from flint taphonomic attributes. Placing each site within the range and scope of regional and local processes of exposure and burial by using informed and critically-evaluated data helps to create a more robust regional archaeological data base. We suggest that our approach is useful in other arid zone contexts and may have implications for understanding Pleistocene population movements across such regions.

Reassessing the lower stratigraphical complex of Grotta Romanelli (Lecce, southern Italy)

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Grotta Romanelli (Lecce, southern Italy) is one of the most important Quaternary caves in Italy, known since the end of the 1800s. The long stratigraphic sequence preserves an extraordinary archaeological and paleontological archive for the understanding of palaeo-landscapes evolution and human-environment interactions from the Middle Pleistocene to the early Holocene.

The recent systematic research, resumed in 2015, together with the new geoarchaeological approach and the revision of the collections belonging to previous excavations, provide a large amount of new data on the chronostratigraphic framework, the paleoenvironmental setting, the faunal spectrum, and the techno-economic behaviors.

Here, we present new data on the lowermost stratigraphic units inside the cave (ISU), which are much older than previously thought. According to a recent litho-, morpho-, and chrono-stratigraphical re-assessment, supported by new U/Th dates, the ISU1 and ISU2 (levels K and I *sensu* Blanc 1920) were referred between MIS 9 and MIS 7, whereas the ISU 3 (level G *sensu* Blanc 1920) was attributed to MIS 5e.

The revision of the lithic collections, coupled with the study of the artefacts from new excavation, highlighted an expedient lithic technology mainly focused on the production of undifferentiated flakes on local limestone. Vertebrate assemblage is mainly composed of birds, megaherbivores, suids, bovines, cervids, rabbits and few carnivorans. The small vertebrate assemblage is characterized by the presence of small mammals (rodents, bats and insectivores), fishes, reptiles and amphibians.

Additionally, we discuss this lithic and fossil record in the new chrono-stratigraphic and paleoclimatic setting as well as in the penecontemporaneous cultural framework of the southern part of the Italian peninsula.

Submerged Palaeolandscapes of the Southern Hemisphere (SPLOSH) – What is emerging from the Southern Hemisphere

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The study of submerged coastal landscapes and human occupation records has rapidly emerged as a key topic in Quaternary science in the last decade aided by new and higher-resolution technologies and focused research programs. These are only beginning to be translated into the Southern Hemisphere where with its wide range of latitudes (from ~12ºN to ~56ºS) and climatic and biogeographic contexts, present a whole suite of different challenges and opportunities. Funded by INQUA for 2020 – 2023, Submerged Palaeolandscapes of the Southern Hemisphere (SPLOSH) focus group was set up to raise awareness and to help strengthen the importance of submerged landscape research in this region. We provide an overview of current knowledge in South America, Southern Africa and Australasia and explore how new palaeogeographic and palaeoecological research, alongside related coastal archaeology, is helping to map out future directions for submerged cultural landscape research in these regions. A common theme across is the need to raise awareness of submerged cultural resources and the multi-disciplinary approach needed to understand the unique landscapes in which they are preserved.

The "Lake of Olympia": Geoarchaeological evidence of a mid- to late Holocene lake environment in the vicinity of ancient Olympia (western Peloponnese, Greece)

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Ancient Olympia is located at the northern fringe of the Makrisia basin at the confluence of the Kladeos and Alpheios rivers. The entire area was affected by strong tectonic uplift of minimum 13 m to 30 m since the mid-Holocene. Our study presents evidence of a large lake environment near Olympia. The "Lake of Olympia" covered large parts of the Makrisia basin, with the ancient site of Olympia directly located at the northern shore. The Alpheios River, flowing through the lake, was naturally dammed at a narrow breakthrough valley across the hills of the nearby Drouva ridge.

Limnic sediments were retrieved at various locations in the Makrisia basin, i.e., at the western and southern fringes as well as in the immediate surroundings of ancient Olympia. These findings are supported by Direct Push sensing and geochemical data. Additionally, micropalaeontological studies reveal the existence of fresh-water ostracods within these limnic sediments. Based on radiocarbon ages, the "Lake of Olympia" existed at least until the late Bronze Age and again during several periods in Antiquity. The fluctuating water level was primarily controlled by the natural bedrock sill of the Drouva ridge. Water level was influenced by tectonic processes, and anthropogenic control at the narrow breakthrough situation may be assumed.

We suppose that the "Lake of Olympia" was used to provide adequate water supply during summer months for the visitors of the ancient Olympic Games as well as the livestock needed as supply for food and sacrifices. Furthermore, shallow water conditions at the eastern fringe of the lake would easily allow to cross the large valley of the Makrisia basin.

Postglacial environmental and human habitation dynamics in the north-eastern lowlands of Romania, derived from a new peat archive and archaeological data

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Anthropogenic activities have impacted global land cover and climate for millennia and climatic and environmental conditions have always been the main factors for human settlement dynamics. This study builds on the first record of environmental history at the western extremity of the Eastern European forest-steppe zone (NE Romanian lowlands), derived from the Dersca-Lozna fen archive, that could explain postglacial human habitation dynamics in this understudied area. To assess fen development and erosion dynamics at the local scale, we derived downcore lithostratigraphic information, bulk density, and humidity values over a continuous time window that spans the last ca. 12000 years. Pollen and charcoal analysis were added to reconstruct regional vegetation history and the role of fire in land-use change. To reconstruct the dynamics of human habitation, we surveyed published archaeological studies and traces of human settlement. The archaeological sites database was subjected to morphometric analysis based on relevant factors (slope, proximity to major waterways, and relief) underlining the evolution of preferred environmental conditions for settling. The main results of spatial distribution analysis converge to conclude the following: three hotspots of human habitation throughout millennia have been identified in the study area; as the population number grew, the number of settlements and the altitude range of the populated landscape increased (particularly in the Bronze Age); the sites' expansion followed the accessibility of the valleys and proximity to water resources. These outputs overlap the preliminary paleoenvironmental picture inferred from the peat stratigraphy, revealing a long-term human impact on the landscape. Thus, two major shifts in erosion and vegetation dynamics are apparent in the peat record: the first coincides with the Bronze Age settlement expansion (ca. 3300 years ago), whereas the second corresponds to a new settlement expansion in the Medieval Warm Period (ca. 900-1200 years ago). The Cucuteni-Trypillia Neolithic culture, inhabiting this area for millennia, left no visible traces in the palaeoenvironmental record. Our study has the potential to fill in the gaps regarding habitation dynamics and human-landscape interactions in this area with a long history of human presence and a white spot on the palaeoenvironmental map of Eastern Europe.

Think globally, act locally: A probabilistic model for climate impacts to coastal resources along the Delaware Bay, USA

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The future projections of the global mean sea level (GMSL) reported by the IPCC are based on a range of greenhouse gas emissions scenarios and state that 70% of all coastlines will experience a rise in sea level by 2100 and will continue to rise beyond 2100. However, GMSL projections are insufficient for local assessments, adaptation, and action plans. The probabilistic sea-levels for 21st and 22nd centuries use a global network of tide gauge sites and three Representative Concentration Pathway (RCP) scenarios of gas emissions. Regional and localized probability distributions of sea level rise (SLR) and storm surges can be developed by assimilating GMSL rise and regional tide gauge observations and applying the Sea, Lakes, and Overland Surges from Hurricanes (SLOSH) model. We use a GIS-based interdisciplinary approach to examine and assess the impacts of SLR and storm surges to Delaware Bay coastal zone. This region includes nearly 1600 documented cultural heritage resources; more than half could be damaged or lost by the year 2100 due to SLR, storm surges, and coastal erosion. The archaeological and historic record indicate tremendous cultural diversity for the area, spanning the past 13,000 years, including Indigenous settlements; African diaspora sites; 17th-century European colonies; 18th century industry; maritime endeavors; subsistence and commercial farming; 19th-century prototype resort towns; and sites associated with the Revolutionary and Civil Wars and World War II. Many align with national narratives and world heritage themes; damage will result in loss of historical information, scientific evidence, and cultural heritage. Our integrated geo-database allows for the visualization of impacts to specific locations and landscapes, and temporal and cultural categories of resources. The probabilistic SLR and SLOSH models offer robust predictions of future trends in the Delaware Bay, and the ability to develop localized vulnerability parameters and pro-active management or preservation strategies for threatened sites and landscapes. The results are of interest to historic preservation and natural resources planners, cultural resources managers, Indigenous community leaders, scholars, and the public, illustrating how our actions today play a role in sustaining cultural heritage for the future.

The rock art sites-landscape nexus: the case-study of the Valcamonica

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Valcamonica, an Alpine valley in Northern Italy, has one of Europe's largest concentrations of open-air rock art, representing a preferential case study to investigate the rock art-landscape-settlements relationships.

The rupestrian heritage of Valcamonica extends for c. 90 km along the whole length of the valley, on both sides with areas of primary clusters. The long chronology of human occupation, which spans from the Upper Palaeolithic upto historical times, reflects human behaviour in giving special meaning and values to certain places that lasted and changed over millennia.

Understanding how much this attitude had been influenced by the landscape, according to its natural resources richness, visibility, accessibility, location of the rocks and how the cultural variable might have played is a new research field into which the project PARC-Paesaggi dell'Arte Rupestre Camuna (Landscapes of Valcamonica Rock Art) wants to investigate.

For this work, authors consider the two selected clusters of Luine hill in the lower valley and Paspardo territory in the mid-valley so to access the relationship with the environmental resources, the landscape features and the cultural choices along all the different rock art chronologies of the valley, using a multi-scale analysis. Specifically, for the Luine hill, a geomorphological investigation correlated to the palaeoenvironmental reconstruction of the post-LGM landscape allows us to estimate the Palaeolithic settlement-rock art sites-landscape nexus. For the Paspardo area, the study of archive aerial images, together with the geomorphological and spatial analysis of the sites, according to the different rock art chronologies, and the comparison with the actual high resolution satellite images highlights the possible cultural driven choices in the selection of the rock art sites in the past and the impact on the preservation of the rock art.

Contribution of Sediment flow Connectivity Index (SfCI) application to landscape archaeology investigations

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The integration of the geomorphological analysis in archaeological investigation is essential to describe physical geography and land morphology, to understand the interrelation of natural and anthropogenic surface-occurring phenomena over time and thus to reconstruct the evolution of the relationship between environment and human activities. On the other hand, a better analysis of landforms and the geomorphological processes helps to connect the historical evidences to landscape reconstruction by supporting the archaeological interpretation. Comparative evaluation of archaeological data with other information sources provides several information for a preliminary analysis of sites, for planning and unfolding of field surveys, for understanding of the post-depositional processes and for the description of palaeo-landscapes.

The Sediment flow Connectivity Index (SfCI) is a powerful geomorphic indicator for defining the most sensitive areas to geomorphological modifications in a catchment, in order to reconstruct the palaeo-landscape. The index describes the connection paths of the sediment in lateral and longitudinal directions to the catchment outlet, by considering the connectivity as the connection by sediment transport. The index computation is based on a mapping approach that is the result of the gradient-based flow accumulation of a sediment mobility index, which is in turn a function of rainfall, geotechnical properties of soil and land use by integrating functional aspects within a structural component. As demonstrated by the previous SfCI applications, the index can be used to correlate the effects of the various events that occur in a catchment, since water and sediment displacement conditions, and in turn is conditioned by the morphological evolution.

We present the experimental application of SfCI for a landscape archaeological analysis in order to assess the contribution of the index to potentially recognize and to interpret the historical evidences in the reconstruction of landscape evolution. The investigation was performed in a test area of Apulia (southern Italy) by exploring an interdisciplinary approach that could open innovative research scenarios.

The Holocene fluvial evolution of the Egyptian Nile Valley and its impact on ancient society

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Responses of the Egyptian Nile to Holocene climate change are largely unknown, despite the Nile's central role in the emergence of Ancient Egyptian culture. Over the last decade, to try to rectify this situation, the Theban Harbours and Waterscapes Survey (THaWS) has drilled more than 250 boreholes in cross-valley transects at ancient Thebes (Luxor, Egypt) to study the architecture of the Holocene Nile alluvium and its geomorphological elements; e.g. channel belts, levees, flood basins, fluvial terraces. The work also critically informs on human-environment interactions at this UNESCO World Heritage Site, which includes Karnak and Luxor temples.

Here, we present a novel framework for the Holocene evolution of the Egyptian Nile Valley, based on our geological transects and a high-resolution chronology based on 48 OSL dates and >10,000 pottery fragments that were gathered from fluvial contexts. Our reconstruction reveals a history of dramatic changes in fluvial style, hitherto unknown, but on par with major hydroclimatic changes over the Nile Basin. Valley-wide channel incision and phased fluvial terrace formation occurred from the early Holocene until ~4 ka BP. This progressive valley entrenchment coincides with relatively wet conditions over the Nile Basin of the African Humid Period.

Around 4 ka BP this trajectory changed quickly into rapid floodplain aggradation with progressively the establishment of a single-channel river planform around 2 ka BP – the modern river Nile. Between 4-2 ka BP the Nile was a multi-channel system with high rates of overbank deposition that relocated its branches through the process of avulsion. The 4 ka BP transformation coincides with progressive regional aridification. It is assumed that reduced vegetation cover in the Ethiopian Highlands was the main driver for a pivotal increase in fine-grained sediment supply to the trunk valley, triggering a major response in fluvial style.

Whilst it is known that Ancient Egyptian culture was strongly interconnected with the fluvial landscape, our research highlights the potential role that climate change and river dynamics may have had on settlement patterns, the ritual landscape, and the regional agro-economy.

Millennial scale mid-latitude ice cores from ice patches: a novel proxy for accessing the paleoecology of alpine biomes, the timing of warming events, and the contemporaneity of archaeological records.

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Ice patches are areas of permanent snow and ice that survive the summer months as a result of drifted, wind-blown snow. In general they are not massive enough to become glaciers, although snow in these locations can turn into névé and eventually firn ice through freeze-thaw cycles and compaction. As in other parts of the world, global warming is causing perennial ice patches in the Rocky Mountains to melt, resulting in the release of ancient archaeological materials that until recently were in frozen stasis. The emergence of cultural materials from these environments is the foundation for the field of ice patch archeology, a sub-field of cryospheric archaeology—the archaeology of the frozen world—which is under threat globally due to warming climate. To better understand the nature and potential of the ice patch record, ice patches in the Greater Yellowstone Area and Glacier National Park, USA were cored to recover accumulations of organic materials (lags) that form as debris covered surfaces during melt periods. This paper shares the methods employed. The macrobotanical analysis of the recovered lag contents demonstrate the potential for more than 10,000 years of preserved material to exist in these locations based on *terminus ante quem* radiocarbon dates from the deepest lags recovered. This paper compares the ages of the recovered lags between three ice patches and compares those ages with the ages of the archaeological materials recovered at ice patches. Indigenous partners participated in the planing and execution of these projects and the plant communities recorded in the lags were shared with interested Indigenous and scientific communities, e.g., botanists.

On the Way to the Fluvial Anthroposphere—Current Limitations and Perspectives of Multidisciplinary Research

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Floodplains represent a global hotspot of sensitive socioenvironmental changes and early human forcing mechanisms. In this presentation, we focus on the environmental conditions of preindustrial floodplains in Central Europe and the fluvial societies that operated there. Due to their high land-use capacity and the simultaneous necessity of land reclamation and risk minimisation, societies have radically restructured the Central European floodplains. According to the current scientific consensus, up to 95% of Central European floodplains have been extensively restructured or destroyed. Therefore, question arises as to whether or when it is justified to understand Central European floodplains as a 'Fluvial Anthroposphere'. The case studies available to date show that human-induced impacts on floodplain morphologies and environments and the formation of specific fluvial societies reveal fundamental changes in the medieval and preindustrial modern periods. This presentation aims to contribute to disentangling the questions of when and why humans became a significant controlling factor in Central European floodplain formation, and how humans in interaction with natural processes and other chains of effects have modified floodplains. As a conclusion, we superimpose emerging fields of research concerning the onset of the Fluvial Anthroposphere and provide specific thematic objectives for future multidisciplinary work.

Holocene pedosedimentary archives of the Kassala region of Sudan: first insights into the archaeo-environmental history of an underrepresented land

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Studies upon past climates, natural landscapes, and paleoenvironments of archaeologically pivotal regions of northern Africa have been of paramount interest in the past decades. For some of those regions, the human-environmental nexus, intended as the inseparable mutual agency between people and nature, has been a long-standing research question; yet, for some others, while purely archaeological endeavours have been ongoing for decades, the environmental record is still an archive to be explored. In this study, newly found archaeo-environmental sites from the easternmost stretches of the Sahelian belt, in the Kassala region of Sudan, are presented. Therein, pedosedimentary features that encase rich archaeological evidence and the climatic history of the region are found within a landscape characterized by emerged naked granitoid plutons dotting a vast gravelly pediplain cut by year-round dry riverbeds and colonized by xerophytes and thin ephemeral grass. By means of regional-scale survey, remote sensing, physico-chemical lab analyses, micromorphology, and radiometric dating, the uppermost portion of the Quaternary record was investigated in order to contextualize the Holocene prehistoric, protohistoric, and later archaeological record of the region. The main identified features include (i) African Humid Period buried isoumic soil horizons (mollisol profiles) in lower flat grounds - legacy of water-reliant prairie environments -, (ii) later accretional dusty aeolian deposits intermingled with colluvial gravels and rich archaeological surfaces close to the plutons' foothills - testimony of a climatic deterioration towards aridity -, and (iii) diffuse hydric erosion of the delicate dusty deposits, with consistent soil loss and displacement - outcome of anciently established hyper seasonality leading to present day weather anomalies. In a current environmental context characterized by severe and rapid soil erosion processes that are irredeemably altering the pristine accretional archives, these multi-scalar results are of great importance as a contribution to a more holistic understanding of past human economies of the region, as well as representing newly added tiles to the recent climatic history of the continent.

Characterizing stratigraphic markers of Late Quaternary Mediterranean landscapes (Southeastern France): an integrated approach revealing detailed sedimentary processes and potential archeological taphonomies.

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The great spatial and geographical disparities in Mediterranean human occupations require a better understanding of climatic events, cultural knowledge, morphogenesis and landscape evolution for the study of archeological records. In southeastern France, the Upper Paleolithic, the Mesolithic, the Early and Middle Neolithic periods have few open-air archaeological sites, resulting in a lack of understanding of the complex relationships between human occupations and adaptations to environmental changes (climatic, geomorphological, natural resource availability). Apart from the interpretative bias related to potential cultural habits, it questions the potential and significant impact of environmental parameters on conservative and destructive properties in open-air sites distribution. To overcome this problem, an integrated multi-disciplinary geoarcheological approach has been developed on targeted sedimentary markers of temperate periods suitable for archeological findings and dated from 50 to 3 ka within detrital sequences and calcareous tufa. It combines geochronological methods (^{14}C, OSL), elemental analysis (pXRF), granulometry, calcimetry and spectrocolorimetry with paleoenvironmental (malacology, anthracology) and existing archeological data. The aim is to detect sedimentary indicators of stable *versus* dynamic phases (in the conservation/destruction of sites) within sensitive sedimentary systems from micro- (elemental to stratigraphic) to landscape- scales for more than 15 sites throughout the southeastern France. For the Upper Pleistocene, its applications yield a consistent high-resolution detection and characterization of almost 10 paleosols covering 13 Greenland interstadials some of which dated between 50 ka and 26 ka. Elemental compositions, taphonomic processes and paleoenvironmental data display evidences for stable environment and slow sedimentation dynamics. In postglacial and Holocene calcareous tufa sequence periods of stability match with chalky phases typical of low hydrodynamism and detritism. The final phases of the studied sequences show significant carbonate signals and noisy detrital components translating globally stable environments associated with short and local disturbances. These environmental destabilizations, potentially climato-anthropic, raise questions about archaeological potential. A correlation between these stable phases and archeological potentials and taphonomies is proposed. The high-resolution reading of sedimentary processes close to and off-sites of sequences improve our understanding of some specific continental archives for a better perception of the impact of diachronic multiscale (climatic, geomorphological) environmental changes on human occupations in Mediterranean domain.

Landscape evolution at the Bronze Age tell site Toboliu (Bihor, Romania)

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The interdisciplinary project ‘Living together or apart? Unravelling the development, internal organization and social structure of a complex Bronze Age tell settlement at Toboliu, western Romania’ (see Găvan et al. 2021) aims to analyse Bronze Age settlement activity at Toboliu, which is situated in the eastern part of the Pannonian Basin. Associated land use and landscape development are important key features, and therefore a focus of the paleogeographic landscape reconstruction of the tell’s surroundings. Since the topography is strongly overprinted by current and past agricultural activity the interpretation of archaeological sediments, but also palaeoenvironmental analysis is challenging. To cope with this, requires moving on different methodological scaling levels within the scope of a close archaeological-geoscientific collaboration. For instance, several extensive drainless depressions which surrounds the tell show some characteristics of periglacial relict forms as well as of prehistoric extraction pits. These were sampled in the field with core drillings, analysed geophysically and -chemically, but also investigated for spatial relationships using a high-resolution digital elevation model and magnetographic imagery. The first radiocarbon sample of one depression bottom dates back to the Copper Age. In addition, optically stimulated luminescence (OSL) dating is under preparation to gain information on sedimentation rates.

From site observation to regional interpretation, the influence of multi-scalar approach on soil properties and their archaeological implication: Kurdistan (Iraq)

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Soils are incorporating many different chemical and physical properties and this numerous information is a useful tool for geoarchaeologists and archaeologists. Indeed, soils can give information on climate, human activities, vegetation, and geological or geomorphological features in the present and past times. The different components of soil can be described as punctual observations or mapped at micro-, meso-, and mega scale throughout computing process (machine learning and interpolation) after *in situ* observations. Gathering information from punctual observations or mapping an area is different and will give different interpretations and results on the soil properties. Indeed, archaeologists and geoarchaeologists are looking for answers to their questions, and soil scientists need to know which approach fits the best with the question asked. This presentation aims to clarify the different uses of soil properties for soil scientists and geoarchaeologists who intend to answer archaeological questions.

This study was conducted on two different campaigns in Iraqi Kurdistan in 2019 and 2022. The first one focused on the sampling of 76 soil profiles near former human settlements (24), while the second expedition was designed to map the soil properties of the Selevani plain with 101 profiles and 453 samples taken. Each mission had a different goal, in one case it was to specify the activity in the nearby area of soil sampling, and in the other, it was to map the different soil properties at a regional scale to use them afterwards for GIS analysis linked with settlement patterns. If the performed analyses on soil samples are the same, the interpretation of the results differs, because objectives are different. While the punctual observation will answer a specific local question, the mapping strategy will help for future surveys or statistical observations over the study area. With this case study, we will give two examples of concrete interpretations from these distinct strategies.

Palaeoenvironment and landscape history of ancient complex society in southern Nigeria: a multiscale view

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Geoarchaeology has been transforming our understanding of human-environment interactions across tropical environments, revealing new histories of human landscapes and social complexity. West African environments remain somewhat peripheral to these developments, despite a rich archaeological record. This paper presents the results of new dataset at Igbo-Ukwu, southern Nigeria's earliest complex society dating to the early first millennium CE. Whilst Igbo-Ukwu is world-famous for returning some of the finest intricately crafted metal objects and rich material culture in West Africa, little is known about the environmental settings sustaining such developments. Recent work, integrating landscape-scale geoarchaeological survey, soil bulk and palynological analyses has produced the first records of buried soils and archaeological sediments. pH and particle size distribution analyses offer some preliminary insights on the character of the soil cover at Igbo-Ukwu, mineral sources and processes of soil formation and transport, and implications for preservation of organic and inorganic artefacts. At micro-scale, the presence of illuvial clay, dung, coprophilous fungal spores, and charred material in buried soils is indicative of open vegetation, animal browsing, and domestic activities associated with the ancient settlement. Our integrated multiscale approach has enabled the recovery and correlations of environmental and anthropic records across Igbo-Ukwu's cultural landscape, while also showing the relevance and feasibility of examining buried soil sequence to understand human-environmental interplay in tropical West Africa.

The Early to Mid-Holocene geoarchaeological landscape of Shaqat Jadailah (Southern Rub al Khali, Sultanate of Oman)

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During the Early and Middle Holocene, the currently hyperarid region of Southern Rub al Khali experienced phases of favourable climate with increased rainfall that resulted in playa lakes and the proliferation of vegetation. From the first phases of the Holocene, human groups occupied the area close to the village of Maitan (not far from the border junction between Oman, Yemen and Saudi Arabia) with temporary and long-lasting encampments. This paper presents the results of the geoarchaeological survey and geomorphological investigations carried out in the interdunal area and open-air palimpsests of Shaqat Jadailah. The fieldwork focused on the environmental, socio-economic, and technological changes that stimulated cultural variability and technological innovation in Southeastern Arabia in the Early and Middle Holocene. Here, the identification of Late Palaeolithic and Neolithic sites yields new insights into the ancient landscapes and human mobility patterns across the region. The presence of abundant lithic artefacts, together with grinding slabs, grindstones, fossilized animal bones and ornaments (some from far off marine environments), speaks for the prolonged occupation of the area during prehistoric times. The deflated sediments in the region indicate the prevalence of predominantly arid and hyper-arid conditions, with brief intervals of relatively humid conditions. The sites in Shaqat Jadailah reveal new archaeological horizons for the transition between Early and Middle Holocene, in intimate connection with the palaeoenvironmental record, even when poorly preserved. The rich and diverse lithic record indicates a complex mosaic of population movements, clustering, and connections. Such diversity patterns and occupational strategies suggest a branched vision of cultural evolution in the hunter-gatherers-herders' groups of the region as opposed to linear models. The prominent cultural variability highlighted in the area was compared to data from other parts of Oman, Yemen, Saudi Arabia and the United Arab Emirates, and shows a high and dynamic human presence in this area, which nowadays appears so inhospitable.

Hunting strategies and land uses in the Early Upper Paleolithic (EUP) in the Mt. Ashitaka area, Central Japan

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Mt. Ashitaka is located at the center of the main island of Japan. The Mt. Ashitaka area is a representative research field of the EUP (ca. 38,000 – 29000 cal BP) in the Japanese Islands. Volcanic ashes (Pleistocene tephras) from neighboring volcanos had accumulated in the area and formed the Ashitaka Loam Formation. The Upper Paleolithic (UP) assemblages were found in the Upper Member of the Formation. It consists of alternate eolian depositions of reddish-brown scoria (SC) layers and ten buried paleosol layers, called Black Bands (BB). Clear and high-resolution stratigraphic sequences provide geological contexts for establishing a detailed and reliable UP chronology in the area. The UP is divided into 5 phases in the area and Phases 1 and 2 belong to the EUP. More than 95 archaeological horizons of the EUP from more than 30 sites have been excavated and reported.

Research in soil science clarified that Black bands (BB) in the Mt. Ashitaka area are the Kurobokudo layers (black humic volcanic ash soil) and estimated that they have developed under semi-grassland vegetation resulting from human activities such as burning and deforestation to make man-made ecosystems because they appeared after emergence of the oldest EUP site and climax forests were generally formed even in the late Pleistocene in the area. Archaeological research in the area also clarified that the Kurobokudo layers were only found in a limited range and their distributions roughly coincide with the distributions of the EUP sites. Besides it, recent archaeological research revealed that hunter-gatherers in the Layer BB V period in Phase 1 employed projectile technology, and hunter-gatherers in the Layer BB III period in Phase 2 used trap pits for hunting. Distributions of sites relating to hunting activities are different between both periods. Such information seems to support the hypothesis of artificial modifications of vegetation during the EUP and suggests that such vegetative alterations could have been associated with land uses for hunting (and other activities). Based on them, this paper presents that the Mt. Ashitaka area has a high potential for the study of niche construction by hunter-gatherers in the Late Pleistocene.

Late Pleistocene and Holocene sand dune formation in the Carpathian Basin

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Aeolian sand dunes provide a sensitive archive for the reconstruction of Late Pleistocene and Holocene environmental change and human impact. This is especially true for the Carpathian Basin, where large rivers, such as the Danube, built extensive alluvial fans which were abandoned later, and aeolian processes could reshape their surface in dryer periods of the Late Pleistocene and even of the Holocene, during which human impact continuously intensified in these areas. Though dune fields represent a dynamic environment, the periodical reactivation of aeolian processes led to the development of several dune generations.

Earlier, the timing of aeolian periods was assessed on the basis of geomorphological analysis and a limited number of radiocarbon data. In the past one and a half decades, however, a growing number of OSL data has been published from these areas. The primary objective of the present research was, therefore, to review published and unpublished OSL ages, to assess the temporal and spatial pattern of aeolian activity in the past 20 ka in the Carpathian Basin, and to make regional comparisons.

In the present study, we summarized OSL data obtained from 6 dune fields. In total, nearly 200 ages were considered from 20 sites. In the case of four dune fields, representative dunes were sampled in detail (crest, slope, foredune depression). Thus, the general framework of aeolian history could be outlined, and region-specific features could be identified. Besides, by analysing all the available data, the magnitude and spatial extension of climate and human-induced aeolian activities were also assessed.

Soil-stratigraphic archives and evidence for late Pleistocene Indigenous land use from a dune-dammed endorheic basin in the Sonoran Desert, Arizona, USA

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Drainage networks in the Sonoran Desert section of the Basin and Range physiographic province of southern Arizona have been fully integrated with the lower Colorado river since the early Pliocene (>5 Ma). However, topographically closed basins have developed where migrating eolian sand or basalt flows impede mountain piedmont and/or axial valley drainages. One such basin is located along the eastern margin of the Mohawk Valley in southwestern Arizona. Here, the Mohawk Dune Field has created a linear ~2 x 25 km endorheic basin along the distal Mohawk Mountain piedmont. The recent characterization and dating of eolian, alluvial, and dry playa soil-stratigraphic archives and archaeological remains preserved in this basin (and adjacent areas) are bringing to light an important record of wet-dry cycles and indigenous land use dating back to the latest Pleistocene. Local valley-axis alluvial records document groundwater discharge, low-energy sheetflooding, and major channel incision at ~21-23, 15.5-21 ka, and 10 ka, respectively (cal ^{14}C). Within the basin proper, intensified piedmont flooding and dry playa inundation occurred > 8 ka and again at 2.7-2.9 ka. Compound crescentic dunes developed in the Holocene at 0.08, 0.2, 0.5-0.6, 1.9, and 7 ka (OSL). Older dunes with well-developed soils have yet to be dated but have been assigned to the late Pleistocene. Dune development is linked to the renewal of sand sources along the Gila River and local distal alluvial fan sheetflood deposits using mineralogical methods. Correlation with paleoclimatic proxies suggests episodes of increased flooding in the Holocene are linked to extra-tropical cyclones and atmospheric rivers from 8-10 ka and intensified El Niño-Southern Oscillation climatic patterns after 5-6 ka. Clovis (~13.3-12.8 ka) occupation of the basin occurred adjacent to a small playa presently marked by a mesquite bosque. Although not directly associated with the Clovis locality, the fossil remains of horse, camel, and bison have been identified in the area suggesting large game was likely present during Clovis times. Unfortunately, Clovis-age alluvium along axial drainages was removed by erosion shortly after 10 ka. Future coring work will target late Pleistocene stratigraphic successions that are preserved in the endorheic basin playas and dunes.

Pre-Holocene Human Presence in the Caribbean: Supporting Archaeological Inference with Geochemical Data

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The oldest date of human presence in the insular Caribbean determined so far is between 7,430 and 7,330 years before present (BP). However, charcoal-bearing sediments adjacent to two cave paintings (pictographs), discovered in Cueva El Fustete II in southeastern Cuba, have recently provided three Late Pleistocene age dates. These extraordinary dates, between 17,500 and 13,500 years BP, are within the ranges of other pre-Clovis dates obtained recently from both North and South American archaeological sites, and are significantly older than any of the dates currently available for the Caribbean. If confirmed, these dates would provide new support for coastal migration through the Pacific sea route (the Kelp Highway) into North and South America, and would serve to generate new ideas regarding how humans spread in the Americas, and how, when, and why they first reached the Caribbean. In order to ascertain that these dates come from the charcoal, the Cueva El Fustete II charcoal bearing sediments need to be thoroughly characterized. The main objective of this research is to validate the accuracy of these dates using radiocarbon and uranium-series dating methods. Once proven, they will have strong repercussions on our understanding of the early peopling of the insular Caribbean.

Session 31: Processes and feedbacks during glacial terminations

Perspective on ice age Terminations from absolute chronologies provided by global speleothem records

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Glacial Terminations represent the largest amplitude climate changes of the last several million years. Over ~ 10 ky timescale, large northern hemisphere ice sheets retreat and sea level rises, and atmospheric CO_2 and global temperatures make a full transition from glacial to interglacial levels. Several possible orbital-insolation triggers have been described to initiate and sustain glacial Terminations, and feedbacks between ice sheet retreat, ocean circulation and ocean carbon storage are invoked to explain the unstoppable progression.

Because of the availability of radiocarbon dating, the most recent termination (TI) has been extensively characterized. Yet, it is widely discussed whether this sequence of feedbacks and millennial events, and rate of warming is recurrent over previous Terminations or is unique. Beyond the limit of radiocarbon dating, the chronologies of climate records from ice and marine cores are often developed by tuning to orbital parameters which limits their use in understanding climate dynamics, particularly the response to orbital forcing.

Speleothems provide absolute age control and high-resolution proxy measurements. This archive therefore provides unique records of climate change across Terminations, and additionally may provide the opportunity to tune ice and marine core archives. However, speleothem climate signals are encoded in a number of proxies. Unlike proxies in other archives like ice or marine cores, the climatic interpretation of a given proxy can vary quite significantly among different regions.

In this study, we

- synthesise the available speleothem records providing climate information for Terminations: TII, TIII, TIV and TV.
- present the records based on the aspect of climate encoded in the available records.
- where multiple records are available for a given region, we evaluate the scale of regional coherency in the proxy interpretation.
- examine the effects of different ice volume corrections on the final climate proxy record.
- evaluate whether there are consistent leads and lags in the manifestation of Terminations across different aspects of the climate systems and different regions.
- examine the expression of millennial events during Terminations.
- we speculate on suitable tuning targets among marine and ice core proxies, and discuss what model ouputs maybe most suitable for comparison.

Mean Ocean Temperature during Terminations I-IV and their subsequent interglacials

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Deglaciations are the largest natural global warming events across the Quaternary. During these large-scale reorganizations of the climate system, the planet takes up vast amounts of energy. This energy is largely partitioned between Earth's two dominant surface energy reservoirs on glacial-interglacial time scale: the ocean and the latent heat used to melt continental ice sheets. Thus, global ocean heat content (OHC), in combination with global sea level, are the two key metrics for the determination of Earth's energy imbalance during the Quaternary.
Ratios of noble gases and N_2 trapped in polar ice cores are a proxy for past mean ocean temperature (MOT), which is directly linked to OHC. Since noble gases are inert, their atmospheric abundances on glacial-interglacial time scale are solely dependent on their well understood temperature-dependent solubilities in ocean water. As the atmosphere is well-mixed, a single ice core sample is sufficient to obtain a snapshot of the global ocean's noble gas content, and, through the temperature-dependent solubilities, its heat content. Thanks to high precision mass spectrometry, the 1σ uncertainty of recent MOT reconstructions is on the order of 0.4°C. Consequently, MOT has proven to be a novel powerful proxy for the past climate.
Here we present a new MOT dataset for Terminations II-IV and their subsequent interglacials, based on noble gas ratios in the EDC ice core. In combination with published data on Termination I (Baggenstos et al., 2019), the EDC MOT record now spans the last four Terminations. We find the largest glacial-interglacial change in OHC of about $1.7\cdot10^{25}$J across Termination II, equivalent to 3.0°C temperature change. OHC changes during Termination I, III, and IV were somewhat smaller with $1.4\cdot10^{25}$J (2.6°C), $1.3\cdot10^{25}$J (2.4°C), and $1.2\cdot10^{25}$J (2.2°C), respectively. Our new Termination II data is in good agreement with the recently published Taylor Glacier Last Interglacial (LIG) record of Shackleton et al., 2020, giving further confidence in the robustness of our results. In accordance with Shackleton et al., we find an overshoot in MOT at the onset of the LIG. A similar, albeit stronger overshoot in MOT can also be found at the end of Termination IV.

Evolution of the phase relationship between Antarctic climate and atmospheric CO2 concentrations across the last five terminations

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Antarctic ice cores are a favoured archive to study past climate and carbon cycle changes from orbital to multi-centennial timescales. They record variations in local temperature through water stable isotopes in the ice phase and provide direct reconstructions of atmospheric composition in the gas phase. Understanding the climate- carbon cycle interactions over glacial terminations is important as they represent the largest global climate changes across the Quaternary. Studies investigating the evolution of the phase relationship between Antarctic climate and atmospheric CO2 changes have mostly focused on the last two terminations because of (i) the scarcity of high-resolution paleoclimatic records covering older terminations and (ii) the uncertainties attached to estimates of the age difference between the ice and the entrapped air, reaching several centuries in the Antarctic ice cores.

Here, we present a new atmospheric CO2 record from the EPICA Dome C (EDC) ice core measured with the IGE experimental set-up spanning between 260 and 190 ka, hence including Termination III. With an average temporal resolution of ~300 years, our new record improves by a factor of three the reference CO2 record over this period that was measured on the Vostok ice core. Also, we improved the resolution of δ15N of N2 record in EDC ice core, a gas-phase proxy for changes in surface climatic conditions in Antarctica, across TIII, TIV and TV measuring new samples at LSCE. Additionally, we used new and previously published CO2 record over TII, TIV and TV measured with the Bern experimental set-up.

By combining those CO2 and δ15N records, we quantify with one coherent methodology the phase relationship evolution between Antarctic climate and atmospheric CO2 concentrations without relative chronology uncertainties over the last five terminations. Our analysis suggests a synchronous change in atmospheric CO2 and Antarctic climate at the onset of terminations, while Antarctic climate leads atmospheric CO2 changes by few centuries at the end of terminations. Finally, we use low-latitude climate tracers measured in the EDC ice core gas phase (CH4, δ18Oatm) to investigate at a global scale the possible mechanisms controlling those changes in the phase relationship between carbon cycle and Antarctic climate.

An improved North Atlantic benthic δ18O stack demonstrates precession pacing of Late Pleistocene glacial terminations

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The mechanism responsible for ~100-kyr cyclicity in Late Pleistocene glaciations is one of the most enduring questions in paleoclimate. Characterizing the response of the climate system to orbital forcing requires precisely dated and continuous paleoclimate archives with small, well-defined uncertainties. Distinguishing whether one orbital cycle is more important than another for triggering ~100-kyr glacial terminations requires both an accurate, non-orbitally tuned age model and a statistical measure of orbital influence. Because precession is the shortest cycle, its apparent influence is disproportionately diminished by age model uncertainties and noise in climate proxy records. Untuned Late Pleistocene age estimates for benthic δ^{18}O stacks (e.g., Huybers and Wunch, 2005; Lisiecki, 2010) have uncertainties of ~10 kyr (i.e., half a precession cycle) beyond the range of radiocarbon dating.

We investigate the roles of precession and obliquity in triggering terminations by measuring the orbital phases associated with termination onset in North Atlantic benthic δ^{18}O records. Non-orbitally tuned ages are generated by correlating North Atlantic ice-rafted debris peaks to well-dated weak monsoon intervals in Chinese speleothems, with age uncertainties less than +/- 4 kyr. Multiproxy probabilistic stacking software, called BIGMACS, is used to generate a 650-kyr stack of eight North Atlantic benthic δ^{18}O records, enhancing the signal-to-noise ratio of the proxy signal. The effects of precession and obliquity on termination timing are evaluated using the Rayleigh's *R* statistic for the orbital phases of terminations, as in Huybers and Wunsch (2005). The stack yields a statistically significant values for both precession and obliquity, with precession having a higher *R* value (0.76) than obliquity (0.66). Thus, we conclude that precession is at least as important as obliquity in triggering glacial terminations.

The last two glacial terminations simulated by an ice sheet – climate coupled model: similarities and differences

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Glacial terminations are marked by a large-scale ice sheet collapse and a re-organisation of all the components of the climate system. These periods are characterised by some abrupt events, both in terms of sea level rise and in terms of climate shifts. The glacial terminations thus provide an unique opportunity to study the interplays between ice sheet and climate changes within a multi-millenial gradual warming context.
Here we use an ice sheet model synchronously coupled to an Earth system model of intermediate complexity to explicitly take into account the different feedbacks at play. We follow a similar methodology to simulate the last two terminations in order to explore the sensitivity of the climate and ice sheet trajectory to the forcings.
We show that the simulated ice sheet geometry evolution is in overall good agreement with available global reconstructions for the last termination. Large-scale grounding line instabilities are simulated both for the Eurasian and North American ice sheets even though the past abrupt sea level rises are underestimated, possibly because the climate model underestimates the millenial-scale temperature variability. In our model, Atlantic oceanic circulation is strongly sensitive to freshwater flux from ice sheet melting and abrupt warming phases in Greenland are linked to oceanic circulation recoveries. The penultimate deglaciation resembles the last deglaciation with a more rapid ice sheet collapse because of stronger insolation forcing. Our model produces a Greenland ice sheet contribution to sea level rise during the last interglacial of about 2 m of sea level equivalent, in agreement with most recent estimates.

Coupled climate-ice sheet simulations of the last two glacial maxima: why were the Northern Hemisphere ice sheets so different?

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The past two deglaciations (~138-128 ka and ~19-11 ka) had very different histories of climate change, for example in the timings and magnitudes of their abrupt temperature and ocean circulation changes. A key contribution to these differences is the contrasting configurations of the Northern Hemisphere ice sheets during the glacial maxima immediately preceding the deglaciation (the Last Glacial Maximum, LGM, ~21 ka; and the Penultimate Glacial Maximum, PGM, ~140 ka). These vast ice sheets exerted an important control on the initial climate state for the deglaciation through their topographic, energy balance and meltwater influences, and hence on the subsequent chain of events, thus impacting the climate, ocean and sea level evolution during deglaciation. In this context, it is extremely useful to be able to examine the complex physical interactions between the climate and ice sheets in order to understand how and why the different configurations of North American and Eurasian ice sheets formed in the two time periods, the commonalities between these two glacial maxima states, and the ice sheets' intrinsic vulnerabilities to changing climate.

Here, we present the results from coupled climate-ice sheet simulations of the PGM and LGM performed using the fast general circulation model FAMOUS coupled to an ice sheet model; FAMOUS-ice (Glimmer-CISM and BISICLES). The simulations follow the PMIP4 glacial maxima protocols (Ivanovic et al., 2016; Menviel et al., 2019), but have dynamically evolving Northern Hemisphere ice sheets. Embracing the uncertainty in choices for model input (including parameter values), we have adopted a large ensemble approach, producing a range of physically consistent ice sheet and climate states for the glacial maxima. We have developed a set of metrics based on a synthesis of climate and ice sheet data, against which we are able to evaluate the model performance and filter out any implausible LGM and PGM conditions. We can thus estimate the uncertainty in our results, examining the relative importance of uncertain model parameters for each time period and their effect on the simulated processes and feedbacks between the climate and ice sheets.

Abrupt climate changes in the last two deglaciations simulated with different Northern ice sheet discharge and insolation

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There were significant differences between the last two deglaciations, particularly in Atlantic Meridional Overturning Circulation (AMOC) and Antarctic warming in the deglaciations and the following interglacials. Here, we present transient simulations of deglaciation using a coupled atmosphere–ocean general circulation model for the last two deglaciations focusing on the impact of ice sheet discharge on climate changes associated with the AMOC in the first part, and the sensitivity studies using a Northern Hemisphere ice sheet model in the second part. We show that a set of abrupt climate changes of the last deglaciation, including Bolling–Allerod warming, the Younger Dryas, and onset of the Holocene were simulated with gradual changes of both ice sheet discharge and radiative forcing. On the other hand, penultimate deglaciation, with the abrupt climate change only at the beginning of the last interglacial was simulated when the ice sheet discharge was greater than in the last deglaciation by a factor of 1.5. The results, together with Northern Hemisphere ice sheet model experiments suggest the importance of the transient climate and AMOC responses to the different orbital forcing conditions of the last two deglaciations, through the mechanisms of mass loss of the Northern Hemisphere ice sheet and meltwater influx to the ocean.

Sensitivity of millennial-scale climate oscillations to boundary conditions in HadCM3 glacial simulations

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Romé et al. (2022) present a new set of long-run Last Glacial Maximum experiments with millennial-scale climate oscillations between cold and warm modes. These oscillations are triggered by different snapshots of ice-sheet meltwater derived from the early stages of the last deglaciation. The overall characteristics of the oscillating events share similarities with $\delta^{18}O$ records of the last glacial period. We test the robustness of these oscillations under different climate conditions, such as those resembling Marine Isotope Stage 3 when multiple abrupt climate transitions, called Dansgaard-Oeschger events, occur. We present the results of multiple sensitivity experiments with modifications to the original simulations including adjustments of atmospheric CO_2 concentration, orbital parameters, and ice sheet geometry to those more comparable to Marine Isotope Stage 3. These experiments were run with intentions to better understand the range of conditions the oscillations can be sustained within the model and provide additional insight into the triggering mechanisms that control abrupt climate changes. The results also show how the adjusted climate conditions effect the time and periodicity of the oscillations and how this could relate to the changing periodicity of observed Dansgaard-Oeschger events.

Multi-millennial scale climate variability driven by bi-polar seesaw

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Millennial time-scale climate variability, which appears during glacial periods including the deglaciation, is characterized by an abrupt warming over Greenland and a gradual cooling over Antarctica, which are called the bi-polar seesaw. These climate changes and the bi-polar seesaw are often related to the drastic strengthening of the Atlantic Meridional Overturning Circulation (AMOC). Despite its importance on the evolution of ice sheets, carbon cycles and human beings, the driving mechanisms of DO cycles remains elusive. Here, from an analysis of intrinsic oscillation of Atlantic Meridional Overturning Circulation (AMOC) obtained from a comprehensive climate model and from nudging sensitivity experiments, we show that gradual changes in the amount of brine rejection from sea ice over the Southern Ocean due to the bi-polar seesaw can drive the AMOC variability. The strengthening of the AMOC gradually increases the brine rejection and its freshwater transport over the Southern Ocean. This change in sea ice then causes a weakening of AMOC by increasing the stratification of the deep ocean and by reducing salinity of Antarctic Intermediate Water that flows into the North Atlantic Deep Water formation regions. Our results suggest the important role of bi-polar seesaw in driving multi-millennial time scale climate variability.

Ross Ice Shelf retreat and ocean dynamics during the Last Glacial Termination: insights from the Joides Basin, Ross Sea, Antarctica

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Quaternary glacial terminations are periods of rapid warming during which climate and carbon cycles experience large-scale reorganization. The last glacial termination (ca. 18-11.5 Ka), in particular, is the temporally closest timeframe from which we can gather information regarding processes and feedbacks that lead to such climatic reorganization. Here we present results from the Southern Ocean, a region which during the Last Deglaciation was affected by strong CO_2 outgassing in relation to the resumption of the thermohaline circulation and ice shelves retreat. Our study focuses on a series of sedimentary cores collected in the JOIDES trough, Ross Sea. The studied area is characterized by complex ice shelf-ocean dynamics and represents one of the sites of Antarctic Bottom Water (AABW) formation which originates from a mixture of cold Ice Shelf Waters (ISW) and impinging modified Circumpolar Deep Water (mCDW) from the outer shelf.

Sea ice and open water dynamics, including information on trophic levels and paleo-seawater temperatures, were reconstructed using a suite of organic biomarkers that includes Highly Branched Isoprenoids (e.g. $IPSO_{25}$ and HBI III), sterols (Brassicasterol and Cholesterol) and Glycerol Dialkyl Glycerol Tetraethers (GDGTs). Biomarker profiles were also compared to bulk organic carbon and stable carbon isotope data ($\delta^{13}C$), as well as sedimentary facies reconstructed from grain-size information, XRF analyses and IRD presence.

Our results depict a coherent and rapid transition from a sub-ice shelf environment (during the Last Glacial Maximum, LGM) to a distal ice shelf system, evolving then into an open marine system. At the LGM the coring site was covered by the paleo-Ross Ice Shelf. Impinging warm waters at the onset of the deglaciation likely caused the paleo - Ice Shelf to retreat southward, freeing the JOIDES trough from the thick ice cover and allowing pelagic primary productivity. Enhanced upwelling of warm and nutrient-rich waters (presumably paleo mCDW) caused persistent blooming of the open water organisms during the whole deglaciation, stabilizing during the Holocene.

Collectively, our datasets illustrate the value of combining environmental organic proxies with sedimentary facies for the reconstruction of rapid changes in glacio-marine environments.

Multi-proxy agreement on Atlantic circulation dynamics during the last deglaciation

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Uncertainties persist in the understanding of the Atlantic Meridional Overturning Circulation (AMOC) and its response to external perturbations such as freshwater or radiative forcing. Abrupt reduction of the AMOC is considered a climate tipping point that may have been crossed when Earth's climate was propelled out of the last ice age. However, the evolution of the AMOC since the Last Glacial Maximum (LGM) remains insufficiently constrained due to model and proxy limitations. Here we leverage information from both multi-proxy data and climate model simulations to constrain the Atlantic circulation over the past 20,000 years. This is facilitated by the explicit implementation of the ocean proxies $\Delta^{14}C$, $\delta^{13}C$, εNd, and $^{231}Pa/^{230}Th$ in our model, allowing for a direct model-data comparison. We find a coherent picture of a shallow and weak AMOC during the LGM that reconciles long-standing conflicting proxy evidence. Model-data assimilation of the last deglaciation, with fully transient simulations starting from this new, multiple constrained LGM state, indicate a muted AMOC response during Heinrich Stadial 1. The relatively small changes from the LGM to the Heinrich Stadial 1 in AMOC are therefore in conflict with the proposal that an AMOC collapse triggered the early deglacial rise in atmospheric CO_2 and instead favor mechanisms associated with the Southern Ocean/Pacific. We further find that the water mass geometry did not fully adjust to the strong AMOC reduction during the comparably short Younger Dryas period. Our results thus demonstrate that even relatively small freshwater fluxes can substantially perturb the AMOC, which implies an increasing risk for its future stability under anthropogenic climate warming.

An abrupt temperature and hydroclimate transition in eastern Africa during Termination V

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Over the last few million years, the climate over much of Africa exhibits a long-term drying trend with episodes of high climate variability coinciding with the intensification of glacial-interglacial cycles. Of particular interest, is a shift to drier and more variable conditions noted in the Olorgesailie Formation (Kenya) between 500 and 300 thousand years ago (ka) in which Potts et al. (2018) observed a turnover of ~85% of large-body mammalian fauna to smaller-body related taxa and suggested that the shift was an evolutionary response to better adapt to the changing climate. However, an erosional gap in the Olorgesailie record during this time interval means that the cause of this faunal shift is still an outstanding question. To understand East African climate variability during the Mid-Pleistocene, we analyze Lake Malawi drill core MAL 05–1 (~11ºS, 34ºE) to investigate if a specific climatic event stands out as a possible driver of the dramatic change observed in the East African mammal community. We use organic geochemical proxies including branched glycerol diaklyl glycerol tetraethers (brGDGTs; the MBT'_{5ME} index) and leaf wax carbon and deuterium isotopes to develop high-resolution temperature, vegetation, and precipitation records, respectively, between 600 and 200 ka. Results show an abrupt temperature increase of ~9°C occurring in less than 3000 years during Glacial Termination V, which is the Marine Isotope Stage (MIS) 12 to MIS 11 transition at ~430 ka. Preliminary leaf wax deuterium isotopic values show an enrichment that coincides with deglacial warmings suggesting a shift to more arid conditions during interglacial than in glacial periods. This change from a cold/wet glacial to a warm/dry interglacial contrasts with the cool/dry pattern of the Last Glacial Maximum (LGM) in East Africa which transitioned to a warm/wet Holocene. Leaf wax carbon isotopes are presently being analyzed to understand past shifts in C_3 vs C_4 vegetation type, which can be related to climatic conditions. We propose that the major warming and drying during Termination V in East Africa represents a significant abrupt change in the climate of eastern Africa and was a likely driver of the major faunal turnover noted in the region.

Glacial-interglacial carbon cycle dynamics of the past 800 kyr in an isotope-enabled Earth system Model of Intermediate Complexity

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Marine sediment and ice cores preserved biogeochemical evidence of carbon transfers between land, ocean, and atmosphere in connection with the temperature and sea ice fluctuations of past ice age cycles. These carbon transfers and the underlying sensitivities of these carbon reservoirs to radiative changes remain poorly understood. Numerical studies proved the potential of several physical and biogeochemical processes to alter atmospheric CO_2 under steady-state glacial conditions. Yet, it is unclear how much they actually affected carbon cycling transiently during repeated glacial cycles. Addressing this uncertainty, we produced a simulation ensemble of various physical and biogeochemical carbon cycle forcings over the repeated glacial inceptions and terminations of the last 800 kyr with the Bern3D Earth system model of intermediate complexity. With this ensemble, we assessed the potential and pathways of different physical and biogeochemical Earth system changes to affect carbon and carbon isotope partitioning between atmosphere, ocean, and sediments. We will present results of the simulated Earth system dynamics during repeated glacial cycles and a comparison with multiple carbon, climate, and circulation proxy time series. Our analysis shows that low glacial atmospheric CO_2 concentrations can be obtained through enhanced C storage in various reservoirs: the deep Pacific and Atlantic, sediments or C burial to the lithosphere. Yet, the associated timing of CO_2 shifts, and patterns of carbon isotope and carbonate preservation change differ and suggest an opportunity to distinguish them in reconstructed changes of $\delta^{13}C$ and sediment composition. In our simulations, the radiative effects of glacial-interglacial orbital, greenhouse gas concentration, and ice albedo changes result in larger carbon transfers between ocean and sediments than atmosphere and ocean, particularly during deglaciations when carbon deposition in sediments is temporarily enhanced. Additional ocean circulation changes have large effects on regional carbon cycling, but they cause smaller fluctuations of atmospheric CO_2 and $\delta^{13}C$ than shown in proxy data. Biochemical controls on the organic matter and carbonate pumps in the ocean have the largest potential to shift carbon between atmosphere, ocean, and sediments and alter their isotopic composition, but no individual process produces data-consistent carbon fluxes in isolation, and their effects add non-linearly when combined.

How much did weathering fluxes change during the last deglaciation? Implications for transient runs with Earth System Models

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During the last deglaciation (ca. 19-11 ka BP), the Earth's climate transitioned from cold and arid to comparatively warmer and wetter conditions. Simultaneously, large ice sheets melted and led to a significant rise of sea level (ca. +120 m), which reduced the size of the exposed continental shelves. Loess deposits were also gradually eroded. These changes influenced the chemical weathering of rocks because weathering rates depend on climate variables (runoff and temperature), land-sea distribution and lithology. Since weathering consumes CO_2 and releases ions (e.g. bicarbonate ions), which increase the river loads of carbon, nutrients and alkalinity, deglacial changes in weathering rates are expected to have consequences for the global carbon cycle. In particular, as a source term in the alkalinity budget, river fluxes can disequilibrate the global ocean inventory, a critical driver of carbon sequestration into the ocean, which is often assumed constant in Earth System Models. In this study, we calculate weathering fluxes using reconstructed lithological maps, and model results from transient runs of the last deglaciation and/or time-slice runs of the Last Glacial Maximum and pre-industrial period. For different models (MPI-ESM, CLIMBER-X, iLOVECLIM, CESM), we compare their evolution and spatial distribution. We show that while the increase of runoff during deglaciation enhances weathering, the rise of sea level and the erosion of loess deposits tend to have a counterbalancing effect on the river loads. As a result, our model ensemble tends to show inconsistent deglacial changes of river loads (e.g. for phosphorus), depending both on runoff biases and on the representation of land-sea distribution. Still, all models indicate a decrease of river alkalinity from the LGM to the pre-industrial. Based on these findings, we discuss the implications of an explicit representation of weathering fluxes for the global carbon cycle in transient runs with Earth System Models.

Carbonate compensation in the glacial Pacific constrained from paired oxygen and carbonate system reconstructions

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The response of the deep ocean carbonate system and $CaCO_3$ dissolution to changes in the carbon cycle ('*carbonate compensation*') is a first order control on atmospheric CO_2 on timescales of ~10^3 to 10^5 years. Although carbonate compensation could account for up to ~*half* of the glacial drawdown of CO_2, quantitative estimates of changes in ocean alkalinity are lacking. As such, the role of carbonate compensation in driving glacial-interglacial CO_2 variations remains poorly understood.

Here, we combine reconstructions of dissolved oxygen from the infaunal-epifaunal benthic foraminiferal $\delta^{13}C$ proxy ($\Delta\delta^{13}C$) and carbonate system reconstructions from boron proxies (B/Ca, $\delta^{11}B$) in benthic foraminifera to quantify changes in both respired CO_2 storage within the deep Pacific during the last glacial, and the response of the carbonate system to this addition/removal of respired CO_2. Our results provide the first quantitative estimates of the amount and timing of alkalinity changes in the deep Pacific over the last deglaciation. Our results indicate an increase in deep ocean alkalinity during the Last Glacial Maximum, and indicate the buffering of the deep ocean occurs substantially faster than the canonical timescale of ~5 kyr (Broecker and Peng, 1987). We also present results from a series of sensitivity experiments and long-term simulations using the recently coupled iLOVECLIM-MEDUSA climate/carbon-cycle/sediment model, with implications for our understanding of carbonate compensation in both glacial times, and the long-term future.

Session 32: Paleo perspectives on a warmer and wetter future Arctic

Speleothem record of warmer and wetter past interglacials in northeast Greenland

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Improving understanding of the Arctic's amplified response to climate warming and the subsequent global consequences can be achieved through investigation of past interglacial periods. While excellent and reliable palaeoclimate records exist for some areas in the Arctic, others are under-investigated, for instance Greenland prior to 130 ka. Northeast Greenland is one of the regions where the effects of Arctic amplification are most intense within the observational period as well as modelled future scenarios. In this study, we investigate speleothems from caves situated in northeast Greenland (80°N), where the current arid climate (ca. 200 mm per year) and frozen ground prevent speleothem deposition. The presence of extensive speleothem deposits in northeast Greenland thus indicates at least one period of wetter and warmer climate in the recent geological past. Based on reproducible ^{230}Th/U disequilibrium dating, the most recent significant speleothem deposition occurred during marine isotope stage 11 (MIS11), an unusually long interglacial with a similar orbital composition as the Holocene, rendering it a good analogue for future climate evolution. Prior to this, the extended MIS13-15 interglacial period was a period of exceptionally prolific speleothem deposition. δ^{18}O and δ^{13}C variability during these two growth phases display large centennial-scale excursions. Furthermore, preliminary investigations into pollen preserved in MIS11 speleothem samples suggest the presence of boreal coniferous species such as *Picea*, *Abies* and *Pinus* as well as others such as *Corylus*, *Alnus*, Ericaceae, Cyperaceae, and Poaceae. These results indicate an environment vastly different to today, where the landscape is largely barren except for a few small alpine plants and shrubs, however, they agree with a record of MIS11 vegetation in a marine core off the coast of south Greenland. While still being under investigation, this could imply that the reconstructed forestation of south Greenland during MIS11 reached further north. The speleothems additionally contain floral macrofossils and large amounts of spores indicating potential for further investigations of environmental conditions in northeast Greenland during a warmer and wetter past.

Overshooting the critical threshold for the Greenland ice-sheet

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Global sea-level rise due to the melting of the Greenland ice sheet poses a severe threat to human society in the 21st century (IPCC, 2021). Modelling and paleoclimatic evidence suggest that rapidly increasing temperatures in the Arctic can trigger positive feedback mechanisms, and the ice sheet is hypothesised to exhibit multiple stable states. Consequently, there are tipping points when the global mean surface temperature crosses specific thresholds (Robinson et al., 2012). Given the current efforts to reduce global emissions of greenhouse gasses, it becomes increasingly unlikely that we will reach the 1.5°C goal by the end of the century. Simultaneously, crossing a critical threshold for the Greenland ice sheet becomes inevitable, and the first early-warning signals of a possible transition have already been found (Boers & Rypdal,2021). However, a short-term overshooting of a critical threshold is possible without prompting a change in the system state (Ritchie et al., 2021). In this study, we use a complex ice sheet model to investigate the effects of different carbon-capture scenarios after crossing the first critical threshold for the Greenland ice sheet. We outline a stability diagram for several emission scenarios and show that temporarily overshooting the temperature threshold may lead to catastrophic consequences in specific scenarios.

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Release of young permafrost carbon during the last deglaciation: Implications for methane emissions at the Younger Dryas – Preboreal transition

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About 19 ky ago, the global climate transitioned from the cold and dry conditions typifying the Last Glacial Maximum (26 – 20 ky Before Present, BP) to the warmer and wetter conditions of the Holocene (11.7 ky BP to Present). In this period, the Northern Hemisphere witnessed a 3.5 °C warming, the demise of the Arctic ice sheets, a 130 m sea level rise, and a profound reorganization of the Arctic permafrost systems that lost about 1000 Petagrams of organic carbon (Pg OC). Simultaneously, the concentration of greenhouse gases rose with sharp fluctuations, the latest and most abrupt of which occurred at the Younger Dryas (YD) – Preboreal (PB) transition (ca. 11.6 ky BP) when natural methane (CH_4) emissions suddenly increased of about 220 parts per billion by volume (ppbv). The abrupt release of petrogenic CH_4 and the destabilization of marine and subglacial methane hydrates were invoked as possible drivers, hypotheses that were challenged by studies targeting the isotopic fingerprint of CH_4 from ice cores. These studies rather proposed a nearly contemporaneous – moderately ^{14}C-depleted – OC source for CH_4 emissions identified in organic matter respired in wetlands. Additionally, the studies discarded relevant contribution from old permafrost OC, but they couldn't constrain the permafrost carbon complexities as permafrost carbon can exhibit a continuum of radiocarbon ages. With this study, we used the Siberian shelf as receptor of permafrost destabilization during the YD-PB transition to help resolving the permafrost carbon complexity during abrupt warming. We targeted lipid biomarkers (lignin phenols and cutin acids) and the C isotope composition (d^{13}C and D^{14}C) of terrigenous OC from shelf sediments deposited off the paleo-delta of the Lena River (Arctic Ocean), which integrates the signal of a vast area dominated by permafrost and sensitive to climate perturbations. Preliminary results warn against seemingly non-negligible contribution to CH_4 emissions from nearly contemporaneous permafrost OC. This study aids in understanding how permafrost systems may respond to current man-induced rapid climate warming, including the possible release of additional CH_4 that would amplify anthropogenic climate change.

Analysis of Early-Warning Signals for Arctic Summer Sea Ice Loss

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The rapid loss of Arctic sea ice in the last decades is one of the most evident manifestations of anthropogenic climate change. A transition to an ice-free Arctic during summer would impact climate and ecosystems, both regionally and globally. The identification of early-warning signals for the loss of the Arctic summer sea ice could provide important insights into the state of the Arctic region.

We collect and analyze CMIP6 model runs that reach Arctic sea-ice-free conditions (area below 10^6 km^2) in summer. Despite the high inter-model spread, with the range for the date of an ice-free summer spanning around 100 years, the evolution of the Arctic summer sea ice area right before reaching ice-free conditions is strikingly similar across the CMIP6 models.

When looking for early-warning signals for Arctic summer sea ice loss, we observe a significant increase in the variance of the sea ice area before reaching ice-free conditions. This behavior is detected in the majority of the models, and also averaged over the ensemble. We find no increase in the 1-year-lag autocorrelation in model data, possibly due to the multiscale characteristics of climate variability, which can mask changes in serial correlations. However, in the satellite-inferred observations, increases in both variance and lag-1 autocorrelation have recently been revealed.

Not gone with the Wind: coastal lake sediment sequence from southern tip of Svalbard records Holocene changes in storminess on human-relevant timescales

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The Arctic warms faster than anywhere else on Earth. This amplified response to on-going climate change is most visibly demonstrated by a dramatic decline in sea-ice extent. As larger areas become ice-free for longer periods of time, winds can interact more with open water – increasing wave height. The ensuing increase in storminess may accelerate coastal erosion and complicates trans-Arctic shipping. But despite these consequences, the magnitude of changes in storminess remain highly uncertain. By extending scarce and sparse instrumental records into past analogues for near-future conditions, continuous and well-dated geological archives of coastal change can close this gap. Here, we present such evidence from a coastal lake sediment sequence retrieved from Svalbard‘s southern tip – an area exposed to the dominant westerly winds. Steinbruvatnet, the targeted lake, is sheltered by a bedrock barrier and experienced little isostatic uplift, so that the distance between basin and coast remained stable since deglaciation. ^{14}C ages derived from terrestrial plant macrofossils reveal that the analyzed ~1m sediment sequence covers the entire Holocene. Employing a novel multi-proxy approach, we provide independent lines of geochemical (XRF), visual (3-D CT) and granulometric evidence for the input of wind-driven sea-spray and clastic input. Our findings suggest a strong coupling between Holocene climate change and the frequency and magnitude of storm events in the region.

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Storegga tsunami or storm? Palaeoclimate, palaeoglacier and sea-level inferences from Ringgåsvatnet, Nordaustlandet, Svalbard Archipelago.

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Analysis of detailed Arctic lacustrine records spanning the Holocene can provide vital information on evolving climate, sea level, and ice sheet behaviour during internals considered analogous to anthropogenically-forced project future climate. Records from climatically sensitive high Arctic settings are of value given their sensitivity to changing environmental conditions. Ringgåsvatnet on Nordaustlandet, NE Svalbard Archipelago is such a case.

The lake situated above 80ºN was cored in 2017. Cores have subsequently undergone analysis to reconstruct their glacier, sea-level and palaeoclimate history. The ice cap of Ahlmannfonna resides within the main catchment of Ringgåsvatnet with meltwater delivery to the lake likely also from the northwest margin of the Austfonna ice cap during deglaciation. The cores record the post-glacial emergence of Ringgåsvatnet with initial isolation of the basin dated to the Early Holocene based on AMS ^{14}C radiocarbon ages on terrestrial macrofossils and foraminifera. Marine and lacustrine sedimentation in Ringgåsvatnet and its post-glacial emergence denote a clear shift in the climate during the Holocene. Within the isolation phase there is a unique sandy layer that is not replicated elsewhere in the core stratigraphy. Based on the current geochronology it is suggested that this may be the first evidence of the Storegga tsunami recorded on Svalbard.

Following lake isolation, a lacustrine environment is dominated by minerogenic input with several phases of sediment variability interpreted as glacial activity. There appears to be no prolonged period of glaciogenic absence from Ringgåsvatnet during the Holocene, suggesting that Ahlmannfonna remained throughout, although it may have remained in a heavily reduced state during the mid-Holocene. This northernmost lacustrine record from the Svalbard Archipelago provides key inferences to Holocene paleoclimates and events in an area where there is sparse prior knowledge.

Unravelling Holocene sea-level and surging glacier histories in central Spitsbergen: a case study from the Erdmannflya lowland

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Detailed reconstructions of Holocene Arctic palaeoenvironments are essential for generating deeper time perspectives on landscape adjustments to changing climate and providing analogues for a postulated warmer future.

Here, as part of the SHERBET project (Svalbard Holocene Emergence and Raised Beach Environments and Timing) we present the latest findings from ongoing work on Erdmannflya, a glacially influenced coastal lowland on the northwest coast of Isfjorden in central Spitsbergen, Svalbard. Detailed UAV and TLS mapping of the area has provided, for the first time, a high resolution understanding of raised beach ridge morphological variation in response to changing wave, current, and tidal conditions through the Holocene of Isfjorden. A new chronology constrained by molluscan and cetacean radiocarbon dates underpins the sea level reconstructions and challenges the assumption that much of western Spitsbergen experienced a Mid Holocene transgression. Further, moraines emplaced within and atop the raised beach sequences, along with high resolution lacustrine cores, permit the elucidation of a history of glacier surges extending well beyond historical records.

Taken together, this environmental-scale reconstruction of Holocene change using a linked raised marine – glacial landsystems approach, shows that a nuanced portrait of landscape evolution can be achieved. That is despite the complexities of rapid isostatic rebound, changing sea ice and wave conditions, climatically or dynamically forced glacial variability, and evolving atmosphere and ocean circulation. The record provides a valuable window into conditions in Isfjorden throughout the Holocene, and challenges a simple interpretation of the early Holocene as an analogue for a future warm Svalbard.

Session 33: Quaternary Glaciations: Processes, Sediments and Landforms

Evidence from geomorphological mapping and paired terrestrial cosmogenic nuclides for a relict cold-based landscape preserved under the Keewatin Ice Divide, Nunavut, Canada

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Relict weathered terrains were recently identified and mapped in large areas formerly covered by the northern portion of the Keewatin Ice Divide, central Laurentide Ice Sheet (LIS), based on high-resolution imagery (Arctic-DEM and Landsat 8), ground-based observations, and surface materials composition. A gradual transition in the preservation of these relict terrains is reflected by changes in geomorphology, weathering, elevation, drainage network, and lake density. Over the Wager Plateau north of Baker Lake, extensive areas of uplands form a continuum ranging from abundant weathered diamictons, bedrock and blockfields, with little evidence of glacial erosion, to terrains with moderate glacial erosion, patchy weathering, sporadic streamlined landforms, a well-developed network of ice-marginal channels, and discontinuous eskers. In the large ice divide migration zone south of Baker Lake, a palimpsest glacial record (striations, landforms and dispersal trains) and stacked till sheets of different provenance reflect persistent warm-based conditions and mobile outflow centres during the last glacial cycle(s). Our classification of these terrains is supported by relative terrestrial cosmogenic nuclide (TCN) abundances in bedrock, till, and boulder samples. Paired ^{10}Be and ^{26}Al abundances are relatively high in relict terrains and apparent ^{10}Be ages of surface bedrock vary from 21.9 ± 0.5 ka to 61.9 ± 1.2 ka (n = 10; LSDn Age ±1σ interior). The pattern of the apparent ages suggests that TCNs produced prior to burial were preserved through incomplete erosion under a polythermal ice divide. The presence of occasional erratics over the weathered bedrock suggests full glacial coverage with sporadic warm-based conditions. In the fully warm-based terrains, apparent ^{10}Be ages on striated outcrops and wave-washed bedrock marine limits vary between 6.9 ± 0.5 ka and 9.0 ± 0.6 ka (n=10) and indicate no exposure inheritance or burial. These exposure ages are not well constrained by other geochronological measurements, and generally suggest that deglaciation occurred at least 1 ka earlier than radiocarbon-based reconstructions. The research captures the deglacial record of the LIS during a critical time and helps to reduce risk to mineral exploration in polythermal glaciated terrain by removing barriers to the use of TCN to quantify glacial erosion and sediment production.

Ice flow dynamics of the northwestern Laurentide Ice Sheet during the last deglaciation

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Ice streaming exerts a strong influence on the mass balance of contemporary ice sheets, accounting for ~90% of the dynamic mass loss of the Antarctic Ice Sheet. Uncertainty in ice stream dynamics limits our ability to predict the future of ice sheets under anthropogenic climate change. Palaeo-ice sheets provide an opportunity to investigate ice stream and ice flow activity over long timescales. A recent ice sheet-wide reconstruction of changes in ice streaming activity for the Laurentide Ice Sheet identifies a number of palaeo-ice streams in the northwest of the Laurentide Ice Sheet where the spatial evolution through deglaciation is poorly constrained and the influence of changing ice source areas during deglaciation is uncertain. According to numerical modelling studies and empirical chronological constraints, this region of the Laurentide Ice Sheet experienced a period of rapid retreat driven by the collapse of the ice saddle with the Cordilleran Ice Sheet during the Bølling-Allerød interval. However, our understanding of the ice drainage network configuration during this period of remains poor and whether saddle collapse influenced the past ice flow dynamics has not been investigated.

Here we use a new glacial geomorphological map based on the ArcticDEM (2 m spatial resolution) to reconstruct the past ice flow dynamics of the northwest Laurentide Ice Sheet following the well-established approach of flowset mapping and the glacial inversion model. The rich detail of the geomorphological record mapped from high resolution data allows us to resolve the configuration and evolution of ice streaming over time. During deglaciation, the northwest Laurentide Ice Sheet experienced dramatic reorganisations with rapid switching of ice flow directions which allow us to understand the changing ice source areas associated with ice saddle collapse. The ice stream network was dominated by a series of time-transgressive ice streams (approx. 50 km to 300 km long), which switched on and off during deglaciation, as opposed to an extensive, long-term-operating ice stream network. This reconstruction provides a possible analogue for future changes in ice streaming in modern ice sheets under a warming climate.

Submarine landforms reveal past Antarctic Ice Sheet grounding-line retreat of kilometers per year

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The ice sheet grounding line is the environmentally sensitive boundary between grounded and floating ice, and its position determines the rate of ice-mass loss to the ocean. Despite advances in the temporal and spatial resolution at which the grounding line can be detected from satellite measurements, it is not known whether the ~50-year satellite record has captured the full range of potential variability in rates and styles of grounding-line retreat. Glacial landforms produced during the last glacial-interglacial cycle and preserved on mid- and high-latitude continental shelves can provide information about ice-sheet behaviour over longer timescales.

Here, we present a stunning assemblage of glacial landforms imaged at sub-metre resolution from an autonomous underwater vehicle in Larsen Inlet, eastern Antarctic Peninsula. The most striking features are a series of transverse-to-flow ridges that are <1.5 m high and spaced 20-25 m apart. We interpret these 'corrugation ridges' to be formed by the squeezing up of soft sediment during the rise and fall of the retreating ice sheet grounding line during successive tidal cycles.

We infer from the spacing of these ridges that the grounding line retreated at a rate of 40-50 m/day (>10 km/year) during regional deglaciation of Larsen Inlet about 11 ka. Although high, our inferred retreat rates for the last deglaciation align with newly acquired satellite observations of rapid contemporary grounding-line retreat in West Antarctica (11.7 km/year). This implies that the maximum magnitude of grounding-line retreat during past and ongoing periods of climatic warming may in fact be even greater than ~50 m/day.

Late Glacial-Holocene glacier fluctuations on sub-Antarctic Kerguelen Archipelago (49°S) based on surface exposure dating with in situ Cl-36, Be-10, Al-26 and C-14

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The Kerguelen Archipelago (49°S) is a group of sub-Antarctic volcanic islands located within the Southern Hemisphere's westerly wind belt in the southern Indian Ocean. The islands demonstrate significant evidence of widespread ice cover such as U-shaped valleys, fjords, erratic boulders and moraines. Nonetheless, Kerguelen has been subjected to very few studies of its Quaternary glacial history. Since glaciers are highly sensitive to changes in temperature and precipitation, glacial fluctuations on Kerguelen may provide insight into the past behaviour of the westerly wind regime. The Cook Ice Cap (CIC) covers a significant part of the western part of the islands, reaching over 1000 m a.s.l. Recent studies have demonstrated significant retreat of the CIC since the 1960s, which has been attributed to atmospheric drying due to the poleward shift of the Southern Ocean's westerly wind belt. The interdisciplinary project SOUTHSPHERE seeks to establish a baseline of the past behaviour of this atmospheric regime by reconstructing Late Glacial-Holocene glacial fluctuations, both spatially and temporally, using lake core records and glacial landforms from region northeast of the CIC.

Geomorphologic mapping of the region outlines several moraine systems associated with CIC outlet glaciers as well as local glaciers, located around 10 km north of the ice cap. Our investigation seeks to substantially improve the Late Glacial-Holocene glacial chronology on Kerguelen through surface exposure dating using *in situ* ^{36}Cl, ^{10}Be, ^{26}Al and ^{14}C. Surface exposure dating of glacial landforms on Kerguelen has previously been done primarily using *in situ* cosmogenic ^{36}Cl given the islands' volcanic origin. During an expedition in 2019, 110 rock samples for surface exposure dating were collected from moraines, scoured bedrock and erratic boulders. This study will produce the first multi-nuclide ^{10}Be, ^{26}Al and ^{14}C analysis of hydrothermal quartz on Kerguelen, which also provides a means of validating nearby *in situ* ^{36}Cl ages. A multi-nuclide analysis is particularly advantageous in this setting, as it exhibits highly active surface processes, strong weathering and high erosion rates. Such an analysis will allow for larger scale investigations of exposure histories, erosion rates, and overall landscape dynamics in the region.

Reconstruction of Late Pleistocene-Holocene East Antarctic Ice Sheet variations through the integrated analyses of marine sedimentological indicators from Terra Nova Bay, Ross Sea.

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Asymmetrical glacigenic structures known as Grounding Zone Wedges, emerging from the Ross Sea continental shelf, owe their origin to the Antarctic Ice Sheet erosive action and transport capability. Those deposits, mainly constituted by glacial till, overlain by glaci-marine and marine sedimentary sequences, witness episodes of sea-level still-stands which are possibly linked to climatic variations.
Our study area, within Terra Nova Bay, is located offshore the Western sector of Ross Sea, where numerous studies have been carried out regarding the post-Last Glacial Maximum deglaciation patterns and the consequent Grounding Line retreat path of the East Antarctic Ice Sheet.
Two sediment cores retrieved from the topset of an exposed, well-preserved Grounding Zone Wedge near Adélie Cove constitute the basis of this research, which comes as a part of the broader DISGELI-PNRA project.
The lithological and textural composition of the analyzed sediment, together with semi-quantitative geochemical data obtained through XRF analyses and organic carbon data derived by CHN analyses, allowed to trace the recent behavior of the East Antarctic Ice Sheet in terms of depositional environment shifts. Radiocarbon dating performed on the bulk organic matter allowed to obtain a time constrain for the basal till deposits found in sediment cores, overlain by meltwater deposits and regular open-marine sedimentation.
Multi-disciplinary studies of glaci-marine sedimentary sequences constitute an effective method to provide a connection between submarine deposits and recent climatic events, highlighting minor changes occurred during the Quaternary.

Large canyons and sedimentation changes indicate extensive early-Quaternary glaciations of the Barents Sea

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Climate proxies reveal a decrease of 4-6º C in global temperature associated with the onset of the Northern Hemisphere glaciations in the early Pleistocene. Sedimentary records of these early glaciations are sparse on paleo-shelves, yet sedimentary trough mouth fans formed on adjacent continental slopes provide a continuous record of the ice-sheet and climate development throughout the Quaternary. Here, we interpreted new high-quality 3D seismic reflection data combined with borehole and chronostratigraphic information from such a location in the western Barents Sea to study meltwater and sediment input to the deep ocean focusing on the on-set of glaciation on the Arctic margins. Sandy deposits were brought to the slopes of the high-latitude Bear Island Fan by a contourite-turbidite system prevailing at the onset of the Quaternary, about 2.6-2.4 Ma. From 2.1-0.9 Ma, muddy sediments were delivered from turbidites and debris flows originating from six canyons measuring up to 12 km in width and 200 m in depth. The large canyons on the shelf and associated downslope deposits document an increased meltwater input to Bear Island Fan during the obliquity-dominated Milankovitch cycles. During the subsequent eccentricity-dominated cycles, rapidly-deposited glacigenic debris flows and mega-scale glacial lineations document a reduced meltwater contribution. This study shows that this Arctic shelve was extensively glaciated in the early Quaternary, with increasingly enhanced meltwater and sediment contribution from the shelve to the slope.

Palaeo-ice margin oscillations in the area of Pleistocene continental glaciations (northern Poland) inferred from combined OSL and Be-10 dating

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Ice sheets and glaciers are good indicators of climate changes. They tend to stay in equilibrium with the mean regional climate, but they also react to any long-term variations of temperature and precipitation by their mass balance adjustment. However, our knowledge about interactions of the Pleistocene palaeo-ice sheets with past climatic fluctuations is limited, as glacial geological record is fragmentary and in many cases difficult to date. In order to explore interactions between palaeo-ice sheets, such as the Fennoscandian Ice Sheet (FIS), and the Pleistocene climatic fluctuations, it is important to link available geological records with robust chronologies of palaeo-ice sheets advances and retreats.

Here we present the chronology and a reconstruction of the dynamics of palaeo-ice margin oscillations based on combined luminescence and Be-10 surface exposure dating. We focused on the southern fringe of the last FIS in northern Poland. The study area covers the region of a fresh glacial landscape shaped in the Late Pleistocene during the last FIS advance and retreat, which in this part of the north-central Europe occurred around 22–18 ka BP. The luminescence (OSL) method was used to date aeolian and outwash deposits intercalating basal till layers. The most likely age of the till layers was constrained by Bayesian modelling integrating sediments sequence with numerical dating controls. The Be-10 method was used to date erratic boulders left by the last FIS and which rest at the surface of a conspicuous moraines. We present 11 new OSL ages and 10 Be-10 ages (5 new and 5 already published).

Our results show highly dynamic oscillations of the palaeo-ice margin with at least three ice advances and three ice retreats in the period between ca. 19-17 ka BP. We attempt to correlate these oscillations with the north-central European glacial stratigraphy, and with paleoclimatic records available from global and regional archives, such as: ice cores, marine sediments, lake sediments and loess sequences.

Surging palaeo-ice lobes of Latvia

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This study focuses on palaeo-ice lobe dynamics and possible surge behaviour in Latvia reconstructed from the glacial landform record. The availability of the 1-m-resolution LiDAR digital elevation model (DEM) has promoted the identification and mapping of previously undetected geometric ridge networks interpreted as crevasse-squeeze ridges (CSRs), which have been widely used nowadays to identify the modern and recently also the Pleistocene glacier surges. We have found the spectacular and well-preserved patterns of CSRs in two Latvian lowlands (Kursa and Eastern Latvian) characterized by fast-flowing/surging ice lobes. Both locations have CSRs across almost the whole width of ice lobes superimposed on mega-scale glacial lineations (MSGLs) and have experienced rapid ice-lobe shut-down and downwasting during the deglaciation, and formation of vast proglacial lakes. The internal structure of CSRs suggests bottom-up squeezing of glacier bed substrate (mostly subglacial till) into the transverse, slightly oblique, and occasionally even criss-cross pattern basal crevasses. Furthermore, the zig-zag pattern of even more than 10-km-long continuous CSRs has been recognized. These CSRs consist of ridges with connected segments oriented even 90 degrees to each other. Altogether more than 13 000 CSRs were mapped, and the average height of CSRs is only 1,5 m but the average length is 0.15-0.22 km. The glaciofluvial landform record allowed to access meltwater-related processes. In the case of the Kursa Lowland, meltwater-related landforms are rare except of proglacial lake sediment-covered plains, but the Eastern Latvian Lowland comprises meltwater channels, tunnel valleys, sandur plains, only some eskers and vast proglacial lake plains suggesting abundant meltwater that what was drained after the surge events. The repeated surging activity was also determined in the Eastern Latvian Lowland, which has at least four end moraine complexes related to the Lubāns Ice Lobe marginal positions during deglaciation. We provide one of the first evidence of possibly surging behaviour of ice lobes in the SE sector of the FIS, Latvia, from the record of CSRs and other glacial landforms and rise the important question that should be answered in further studies – what was the mechanism and timing of palaeo-ice stream/ lobe surging?

Unravelling the Early Pleistocene Glacial Landscape in the Swiss northern Alpine Foreland

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The Early Quaternary in the Swiss northern Alpine Foreland was characterized by a transient and low relief landscape, when about four to eight glacier advances sculptured the northern Alpine Foreland. Landforms related to these advances are absent and sediment packages are scarce, thus laterally and horizontally discontinuous. They are preserved in a succession of glaciofluvial gravels intercalated with glacial and/or overbank sediments, so-called Cover Gravels (*Deckenschotter* in German). This study underscores the Early Quaternary stratigraphy in the Swiss northern Alpine Foreland by exploring some 30 Deckenschotter sites in detail. The analysis of the origin, transportation mechanism, and depositional environment, and the application of the established cosmogenic ^{10}Be and ^{26}Al chronology revealed five Pleistocene glacier advances between ca. 2.5 Ma and ca. 250 ka. Three of these glaciations occurred during the Early Pleistocene prior to the Mid-Pleistocene Transition (MPT): the first one at ca. 2.5 Ma appearing to be synchronous with the onset of Quaternary glaciations in the northern hemisphere, the second at ca. 1.5 Ma, and the third at ca. 1 Ma. The younger advances took place during the Middle Pleistocene: one is attributed to the Most Extensive Glaciation (MEG) at ca. 500 ka, and the other after 250 ka. During the early Pleistocene, the occurrence of a complex cut-and-fill arrangement of gravel units suggests that the base level of the rivers draining the glacial meltwaters was at a nearly constant elevation during that time. The phase of cut-and-fill system was followed by a period of incision, which was likely induced by the MPT after ca. 1 Ma, and the relief was consequently lowered. Our study thus portrays a unique case for landscape evolution in forelands where changes in climate during the MPT was possibly an important driving force.

Overdeepened glacial basins as archives for Quaternary glaciations and subglacial processes: A detailed study the Alpine foreland of Northern Switzerland

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Overdeepened glacial basins are typical yet poorly understood elements of glacial landscapes. The 10s to 100s of meters of unconsolidated sediment infilling the overdeepenings are a largely untapped terrestrial archive for Quaternary environmental change and landscape evolution. We present a detailed study on a group of Quaternary overdeepenings in the Alpine foreland of N Switzerland (W Rhine paleoglacier and adjacent lobes). Seismic data and drill cores (ca. 1800 m in total from 11 sites) allowed us to reconstruct the geometry and the depositional evolution of these overdeepenings and the connected downstream fluvial channels. The collected data give a detailed picture of when and how overdeepenings were eroded and infilled, and which subglacial processes were involved. The results contribute to a more complete reconstruction of the repeated extensive glaciation of the Alpine forelands in response to global climatic changes during the Quaternary.

8.2 ka event recorded by a glacier advance in the South Western Alps

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Numerous climate proxies around the globe have recorded a short-lived (centennial-scale) climatic cooling event at 8.2 ka BP, superimposed on the millennial-scale warming trend that characterized the early Holocene. In the Mediterranean region, several paleoclimatic reconstructions based on marine, lake and speleothem records confirm that the 8.2 ka event was short (~150-200 years), cold, arid, and significantly impacted regional ecosystems. However, the relationship between this abrupt change in climate conditions and geomorphological processes is not always straightforward, mainly due to a lack of chronological constraints. This is particularly true in the European Alps where, unlike for other well-known Holocene glacial oscillations, the effect of the 8.2. ka cooling event (i.e the Kromer Stadial in the Alpine glacial chronology) is poorly documented, with no glacial deposits (eg moraines) associated with this change having been dated thus far.

We collected 5 samples from prominent boulders standing on the crest of a frontal moraine in the Maritime Alps, the southernmost part of the Alpine chain, just 40 km inland from the Mediterranean Sea. The moraine is located in a valley where the southernmost glaciers of the Alps (Gelas, Peirabroc, Maledia glaciers) are still preserved, and where the location and age of the Late Pleistocene and Little Ice Age moraines are known (i.e. LGM, Oldest Dryas, Younger Dryas). The ^{10}Be exposure ages of these blocks yielded 10Be exposure ages ranging between 7.9 ± 0.4 ka and 8.2 ± 0.4 ka (average value of 8.0 ± 0.4 ka). These ages consistently indicate that the 8.2 ka global event is registered as a glacial advance in this sector of the Alps.

The results therefore allow us to i) add a fundamental tile to the glacial chronological sequence of the SW Alps, ii) confirm that these marginal glaciers (i.e. close to the Mediterranean Sea) are sensitive to short-lived climatic events, making them ideal indicators of environmental change caused by large-scale far-field climate variability that occurred in the North Atlantic.

Marine ice sheet instability: collapse or steady retreat? Evidence from The Minch, NW Scotland

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The 6th IPCC Assessment Report (AR6) projects sea-level rise between ~0.5 and 0.9 metres by 2100. However, when ice sheet instability effects are considered, this figure may rise to near 2 metres. The deep uncertainties relating to marine ice sheet instabilities stem from a lack of long-term observations. Palaeo-ice streams and large marine-terminating glaciers provide long-term observations via their now-exposed sediment and landform record. IPCC AR6 identifies only two unambiguous examples of palaeo-ice streams which have undergone marine ice stream instability, one of which is the Minch ice stream (MnIS), NW Scotland. The MnIS drained much of the northern sector the last British-Irish Ice Sheet, before undergoing dynamic retreat and possible collapse. This research presents a new chronology from AMS radiocarbon (^{14}C) dates to constrain initial ice-stream retreat and subsequent collapse. This research also employs an innovative multi-proxy approach. This approach combines traditional marine geological techniques – including sediment strength, ice-rafted debris (IRD) grain counting (>2mm), particle size analysis <2 mm (using a Beckmann-Coulter LS230) and foraminifera identification – supplemented by more novel methods, including automated X-ray computed-laminography sediment characterisation and lipid biomarker analyses. The findings focus on the relative roles of climate-driven vs internally driven dynamics in triggering ice-stream collapse and the subsequent nature of this retreat. This work will also help to determine the relative impacts of ice-shelf presence / removal, sea-surface warming, air temperatures and bed topography in (de)stabilising the MnIS before its ultimate disappearance.

Glacial geomorphological mapping of a complex ice-marginal landscape in West Cumbria, UK

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1. Imperial College London, 2. Jacobs

West Cumbria in the north-west of England is located in a former ice confluence zone of the last British-Irish Ice Sheet (BIIS). The confluence of Irish Sea Ice Stream (ISIS), local Lake District glaciers and Scottish ice resulted in a geomorphologically complex ice-marginal landscape along the coastal plain. Previous glacial geomorphological investigations in West Cumbria have focused on the needs and requirements of the site descriptive models at the local nuclear licenced sites (Sellafield and Low Level Waste Repository (LLWR)) to support their respective environmental safety cases. This has mainly focused on developing a regional lithostratigraphy and 3D geological models from Quaternary sediments. The focus on the nuclear industry has resulted in limited research on the glacial geomorphology and the dynamics, patterns, and processes of the BIIS in this area.

Presented is a glacial geomorphological map of West Cumbria covering an area of approximately 100 km^2. Remote mapping was carried out using LiDAR derived digital elevation and terrain models (DEMs/DTMs), combined with optical satellite imagery. This was supported by field mapping and sedimentological analysis to provide a holistic assessment of the geomorphology. This has resulted in a wide range of new glacial and glaciolacustrine landforms being mapped including moraines, kames, kettle holes, proglacial lakes, and meltwater channels. The results have enabled the reconstruction of former ice marginal positions and potential confluence zones of the ISIS and Lake District glaciers during the last glacial events in West Cumbria. The map provides a geomorphological framework which can be used to support and improve the understanding of current and future 3D geological models of West Cumbria.

Greenland Ice Sheet retreat during the Holocene from the mapping of ice marginal landforms

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Understanding past ice sheet retreat is important for constraining numerical models to project future sea level rise contributions. We present the first landform-based empirical reconstruction of Greenland Ice Sheet retreat during the Holocene. Using the 2-metre resolution ArcticDEM, 271,799 terrestrial landforms have been mapped, covering most of the ice-free land around Greenland's periphery. The timing of ice marginal retreat was constrained using published geochronometric dates to produce an ice sheet-wide margin reconstruction from 13 ka to 6 ka. This reconstruction is the highest resolution GrIS-wide chronology and will be used to constrain an ice sheet model.

The morphology, bathymetry and stratigraphic architecture of the Northeast Greenland Ice Stream pinning point in outer 79N fjord.

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Pinning points and ice shelves are critical components in determining the stability of marine terminating outlet glaciers and ice streams. In the Arctic and around Greenland ice shelves and tongues are becoming scarce as accelerated thinning due to surface mass balance change and sub-shelf ocean warming drive buoyant lift-off and ice shelf disintegration. Yet the nature of the physical interaction between ice shelves and pinning points, or how such environments evolve in relation to bed architecture, bathymetry and ocean circulation is under researched. Here we explore the morphology, geometry and sedimentary architecture of Bloch Nunatakker (BN), a pinning point which has served as both an anchor point for the Northeast Greenland Ice Stream (NEGIS) grounding line during deglaciation, as well as a shallow pinning point for the edge of the Little Ice Age/contemporary ice shelf in front of 79N fjord.

The large- scale geometry of the BN pinning point complex is controlled by a tectonic shear margin and intrusive complex composed of dolerite swarms. The bathymetry varies from ~50 m to 500m bsl and the seafloor terrain is composed of undulatory bedrock topography draped and infilled predominantly by deglacial phase glaciomarine and marine sediments. Multibeam and sub-bottom profile data clearly show areas of subglacial areal scour and streamlining, grounding zone wedges and moraines. The sedimentary architecture can be categorized into five distinct acoustic facies with bedrock, stratified basinal infills, deformed sedimentary sequences, subaqueous debris flows and postglacial sub-shelf and aeolian sources all contributing to the unique architecture of this pinning point.

The disappearance of the 79N grounding line and ice shelf at the opening of the Holocene due to increased air and ocean temperatures will be mirrored in the near future as the Arctic region warms. The BN pinning point and the adjacent fjord walls will provide some continued marginal stability for the ice shelf, but this region of the seafloor is unlikely to provide ice shelf stability in future decades.

Insights into the glaciodynamic conditions of subglacial bedform formation from model-data comparison

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Subglacial bedforms (drumlins, ribbed moraines and mega-scale glacial lineations (MSGL)) are abundant across deglaciated terrain. The glaciological conditions under which they form remain poorly understood. This arises from the following conundrum. Subglacial bedforms are difficult to image beneath contemporary ice sheets, meaning we have few observations of them actively evolving. Conversely, in palaeo-landscapes there are a plethora of subglacial bedforms which are more easily accessed, but the ice that formed them is no longer present to link specific conditions to.

In this work, we constrain the conditions of subglacial bedform formation, by utilising a rich palaeo drumlin record in Britain and Ireland, coupled with a well constrained numerical model of the last British Irish Ice Sheet (BIIS). We use this ice sheet model as a substitute for observations of ice conditions and ask under what conditions do bedforms arise? However, linking the model timing to that of drumlin formation is complex. To achieve this, we conducted statistical model-data comparison, analysing 200 numerical simulations of the BIIS between 32 and 15 ka. We quantitatively compare the geometry of modelled ice flow against directions inscribed in 120 drumlin fields, 20 ribbed moraine fields, and all recorded MSGL, to identify potential phases of ice sheet evolution under which the drumlins were formed. We then extract the glacial conditions (e.g. velocity, thickness, shear stress and timing) corresponding to the potential landforming events.

We find that bedforms do not relate directly to a specific ice velocity, thicknesses, or shear stress ranges but instead, their development appears to best match with the cumulative basal velocity. In other words the quantity of ice that directly moves over a point on the glacier bed is the main factor we observe to control landform development. Furthermore we find evidence to suggest landform length may be a result of increased cumulative velocity.

Spatialized investigation of subglacial bedform evolution and bed deformation unravels ice-meltwater-bed interactions

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While they probably represent the most relevant proxies for reconstructing ice-meltwater-bed interactions and ice sheet dynamics, the formation and evolution of subglacial bedforms is nowadays made difficult by the inability to monitor active bedforming processes at high temporal and spatial resolutions. Based on an unprecedented data compilation (~250 000 bedforms) and new morphometric indices we revisit the theory and significance of the subglacial bedform continuum to propose a new model correlating the degree of bedform evolution with the quantity and direction of deformation accommodated by the subglacial bed. We build high-resolution maps of subglacial bed deformation to explore the complex ice-meltwater-bed interactions and unravel the role of ice flow velocity, bed deformability and meltwater routes in bedforming processes. The model and method we propose contribute to perform field-based palaeoglaciological reconstructions of ice domes, ice streams, sticky spots and subglacial drainage routes with unprecedented resolution.

Who is who in the glacial forefield: a macro-fabric based classification of glacial landforms

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Modern day glaciated areas pose as a sandbox model for the description and interpretation of glaciogenic landforms, where cause and effect are well constrained and understood. The description of glaciogenic landforms- or features are usually based on the lithofacies (e.g. diamicton, graded sand, etc.) or on sedimentological processes (e.g. meltout till, push moraine). Certainly, this procedure is well established and suitable when dealing with recent landforms. When it comes to ancient glacially associated deposits or former glaciated areas that are isolated or the general context is vague, interpretation can be difficult or ambiguous. Apart from lithofacies and sedimentological properties, the arrangement and orientation of clasts and glacial debris can be used to classify distinct morphotypes that occur in a glacial setting. For this purpose, we studied ice parallel-, orthogonal- and joint landforms as well as amalgamated deposits in the proximity and direct ice contact of the retreating Gepatsch glacier and Mittelberg glacier in Tyrol, Austria that were analysed according to their clast macro fabric. Based on the data of the spatial distribution and orientation of clasts that are extracted from virtual outcrop models, UAV surveys and classical fieldwork approaches, the analysed features differ significantly according to their fabric patterns and allow a classification supporting the existing terminology that helps to provide an alternative for the understanding of glaciogenic landforms.

Three-dimensional micro-tomography characterisation of fractures in subglacial traction till – towards a holistic understanding of a key variable in engineering geology and hydrogeology

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Subglacial traction till (STT) and related sediments cover over 30% of the Earth's surface and are crucial to our endeavours of building safe infrastructure and extracting clean groundwater. However, due to the large variability in, and seeming unpredictability of, the properties of STT across formerly-glaciated areas, including much of Europe, assessments of ground stability and water conductivity have regularly faced more extreme challenges than sediments deposited by other earth-surface processes. We here present the synthesis of four years of research dedicated to solving a crucial element of this puzzle, namely the role of microscale and macroscale cracks (or fissures and fractures, FF) in STT. While such fractures have been described before, they have never been analysed systematically. Our combined and interdisciplinary approach of macroscale and microscale structural measurements (using modern glaciers in the European Alps and Arctic Sweden and combining this with formerly-glaciated areas in northern Europe) aim to shed light on the role of these enigmatic features. We here present the results of macroscale sedimentological methods (e.g. clast fabric, novel structural measurements of fractures and fissures) alongside engineering geological applications such as X-ray micro-tomography analyses and triaxial load-cell analyses as well as hydrogeological field and laboratory tracer experiments.

Together, these demonstrate that FFs are crucial conduits of groundwater and preferential loci for sediment failure, thereby providing the main predictor of ground (in)stability.

Two clear findings emerge: Firstly, FF patterns are not randomly oriented as hitherto thought, but clearly linked to glacier dynamics (e.g. thermal regime and flow path). Secondly, FF are clearly and systematically linked at micro- and macroscale. We will explore the implications of these highly encouraging findings in this contribution from both pure and applied aspects for the first time here.

Internal composition of glacial curvilineations in NW Poland constrains their origin as erosional remnants of channelized meltwater flows

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Glacial curvilineations (GCLs) were first identified in 2010 in northern Poland and since then they have been documented in numerous other regions overridden by the Scandinavian and Laurentide ice sheets. The origin of GCLs attracts a lot of attention as it sheds light at the subglacial processes and informs our understanding of glacial sediment transport and deposition. So far two contrasting hypotheses of GCLs formation have been formulated: (1) by channelized subglacial meltwater erosion and (2) by bank failures at the edge of tunnel valleys or subglacial lakes.

In this study we investigated geomorphology and internal composition of GCLs in one of the largest drumlin fields in the Central European Lowland, aiming to decipher the mechanism of their formation. Specifically, LiDAR data were used for the geomorphological analysis, and the internal composition was investigated in five trenches at the GCLs' crests and at the adjacent till plain. The area has a distinct NNW-SSE geomorphic trend given by the orientation of drumlins and mega-scale glacial lineations whereas the most prominent geomorphic element, a tunnel valley hosting the GCLs, is oriented NE-SW. All excavated trenches expose massive, matrix-supported diamictons interpreted as subglacial traction till and characterized by distinctly uniform clast fabrics not related to the orientation of the GCLs.

Overall, our data show that the GCLs and the neighbouring till plain are parts of a common antecedent landsystem. No evidence of gravitational sliding from the flanks of the tunnel valley was found. The GCLs are interpreted as erosional remnants of an older landscape carved by channelized subglacial meltwater flows.

The development of low-lying coastal cirques during the transitional phase of the Scandinavian Ice Sheet

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It is well established that during the Quaternary Scandinavia experienced a wide variety of climates from warm, similar to present-day conditions, to full-scale ice sheet inundation during glacial maxima. Under these varying conditions, there would have been periods when all of the high alpine areas would have been covered by an ice sheet or ice cap and cirque glaciers could only have been found in low-lying coastal environments beyond the ice sheet margins.

In the northern part of Scandinavia near the Lofoten islands, 67.5-69.5°N 1732 cirques have been identified, with over 55% lying below 500 m a.s.l. Due to the large number of low-lying cirques, particularly along the coast, they most likely required a cold climate such that a substantial Scandinavian ice cap/ice sheet existed and was probably proximal to them. Therefore, the low-lying coastal cirques must have been occupied by "active" glacial ice just before and just after glacial maxima, compared to the high elevation cirques inland which must have been occupied by "active" glacial ice comparatively early and late during a glacial cycle. While the high-elevation cirques will have been glaciated for much longer it is unclear how long cirques in each location hosted "active" cirque modifying ice. We have identified and mapped 1004 cirques that are proximal to and beyond the YD ice sheet limits and 728 cirques located inside the extent of the YD margin. A statistical comparison between the low-lying coastal cirques, proximal to the ice sheet margin, and the high elevation inland cirques, of various cirque metrics (e.g. slope and aspect), is undertaken in order to elucidate if the low-lying cirques differ from the high elevation cirques. If so can this can be attributed to the duration of active ice occupation or the difference in ice flux or the role of non-glacial processes that were active for most of the glaciation in the low-lying cirques, while the high elevation cirques were covered by cold-based ice. It is hoped that this study can further understanding of glacial landscape evolution in relation to ice sheet geometries i.e. proximal to the ice margin or the ice divide.

Late Pleistocene cirque glaciation in the Simien Mountains, Ethiopia

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High-mountain tropical glaciers have been receding significantly in recent decades as a result of either rising temperature or falling precipitation. The sensitivity of these glaciers to changes in temperature and precipitation is spatially variable and depends on their location within the tropics and height above the 0° C isotherm. In tropical East Africa, Late Pleistocene glaciation was restricted to mountain ranges in Ethiopia, Kenya, Tanzania and Uganda. Regional differences in the timing of glacier advance and recession have previously been linked to differences in glacier sensitivity and variability in climatic conditions across these mountain ranges. To better understand the magnitude of climate change and its cause, we investigate Late Pleistocene glaciation in the Simien Mountains, Ethiopia. We present glacier reconstructions, ELA estimates and new ^{36}Cl ages on moraines. We find evidence for at least two stages of glaciation within the last glacial cycle, with initial ELA estimates between 4000 m and 4200 m asl. The results are compared with other sites across East Africa with respect to timing and glacier sensitivities.

Megaflood and GLOF research opportunities – a personal perspective

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A focus on adaptation to anthropogenic climate change and the effects on the global hydrological cycle, not least glacial recession worldwide, has led to a burgeoning interest in glacial lake outburst floods. For example, the number of scientific papers citing the terms 'megaflood', 'catastrophic flood' or 'glacial lake outburst flood' (GLOF) in the titles has more than doubled in the last decade. Research outputs relate to recent GLOFs, as well as the identification of prehistoric exceptional floods, many dating to the Pleistocene termination. Former dam sites and the associated sedimentary sequences relate to exceptional floods worldwide. Notable has been the acceleration of research on sites in China and South America, as well as across Europe. Case studies, identifying flood landforms, modelling floodwave evolution, and the descriptions of sedimentary sequences from the field, provide repositories of data and interpretation which will aid future investigations. Yet, studies focussed on key generic issues remain relatively few. This presentation will provide an appraisal of progress and highlight opportunities for future research which might provide an improved framework within which to interpret case studies.

Session 35: Dust dynamics through the Quaternary: terrestrial records of climatic and environmental impacts

Quaternary dust size variability in Antarctica: a proxy for air mass subsidence?

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Mineral dust windblown from continental landmasses of the Southern Hemisphere to Antarctica and buried in snow and ice layers represents a key paleo-environmental and paleo-atmospheric proxy that can be studied within shallow and deep ice cores. Here we provide a comprehensive overview of the state of knowledge of Quaternary dust provenance and variability in Antarctica. In particular, we focus on the use of mineral dust grain size oscillations at different timescales as a paleo-atmospheric circulation proxy. Its relationship with the Southern Westerlies and with local subsidence of air masses is discussed in the light of new data from present-day measurements in the atmosphere above Concordia Station (East Antarctica), where a novel optical system (OPTAIR) capable of operating under extreme climate conditions was installed in 2018 in order to investigate year-round the atmospheric dust transport and its optical properties.

Atmospheric dust transport to high-elevation Dronning Maud Land, Antarctica, over the satellite era as observed in a seasonally-resolved ice core record of dust deposition

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Deposition of aeolian mineral dust recorded in Antarctic ice cores is associated with large-scale atmospheric circulation variability. This natural archive can therefore be used to extend knowledge about atmospheric circulation variability in the Southern Hemisphere prior to the satellite era (1979-2017). However, relationships between dust transport and circulation patterns vary regionally across Antarctica. Reliable atmospheric reanalysis datasets over the satellite era are thus crucial for identifying these regional relationships to interpret past dust records and infer past changes in the large-scale circulation.

This study investigates dust transport to high-elevation Dronning Maud Land (DML), Antarctica, through analysis of dust deposition recorded in a new 1300-year ice core recently drilled at Kohnen Station (75°00'S, 0°04'E; 2982 m.a.s.l.) as part of the Isotopic Constraints on Past Ozone Layer in Polar Ice (ISOL-ICE) program. The dust record is examined together with present-day dust transport simulations to the ISOL-ICE ice core site using the Flexpart model, and correlation analysis with atmospheric reanalysis data over the satellite era. An abrupt increase in dust deposition and particle size is observed in the ice core from 1915 to 1930 CE, translating to a 10-fold increase in dust flux and a 12 % increase in the proportion of coarse particles (2-5 μm / 0.9-5 μm) compared to the respective pre-1915 means. Interannual correlations from 1979-2017 between the proportion of coarse particles and atmospheric geopotential height show that cyclonic activity south of South America is an important mechanism by which dust is transported from southern South America (SSA) to high-elevation DML, explaining up to 36 % of variability in dust deposition at the ice core site. Dust transport modeling simulates dust trajectories consistent with cyclonic wind flow in the SSA region, suggesting that SSA as the dominant dust source region for high-elevation DML has not changed significantly since the Last Glacial Maximum based on comparison with previous ice core studies. Furthermore, horizontal dust trajectories are insensitive to particle size, seasonality, and transport height. These findings over the satellite era provide foundational work for interpreting the ISOL-ICE ice core dust record over the last century and beyond.

Late-Pleistocene Paleodust Records from the Guliya Ice Cap (Northwestern Tibet)

Dr. Emilie Beaudon [1], ***Prof. Elizabeth Griffith*** [1], ***Dr. Julia Sheets*** [1], ***Prof. Howie Scher*** [2], ***Prof. Michael Bizimis*** [2], ***Dr. Jim Sexton*** [2], ***Prof. Ellen Mosley-Thompson*** [1], ***Prof. Lonnie Thompson*** [3]

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Pre-Holocene data are too sparse to constrain the composition of aerosols in climate models for the remote inner Asian continent despite that it is Earth's second largest source area for dust. To reduce climate model uncertainties pertaining to mineral aerosols' feedbacks on radiative forcing, this study provides the first datasets of the mineralogical and geochemical composition of aeolian dust preserved in two Guliya ice cores (Kunlun Mountains, Tibet, China). The dust composition is used to trace its geographical source and infer past environmental changes and changing atmospheric influences on the NW Tibetan Plateau. The sensitivity of the Westerlies and the Indian Monsoon system which are associated with abrupt changes in the chemical signatures of the dust is assessed.

The mineralogical, elemental, and Sr-Nd radiogenic signatures of the aeolian dust particles sampled along the two Guliya ice cores are characterized to identify the dust lithological and geographical sources, trace the long-term variability of paleo-hydro-climatic conditions prevailing in NW Tibet, and provide theoretical knowledge on how Holocene paleoenvironmental records are entrained into the ice at the Guliya summit site compared to that at the Guliya plateau site.

Late Pleistocene Sr-Nd isotopes time series extracted from the two Guliya drilling sites are presented. A particular focus is placed on the changing composition of dust through stadial/interstadial transitions recorded in the Guliya core, and on the different stratigraphic features visible in the ice (including the grey clay layers in the oldest part of the record). The results are interpreted in light of the composition of new Potential Source Area (PSA) samples and on previously published regional loess records.

High-resolution palaeodust archive from subantarctic Macquarie Island

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Atmospheric mineral dust drives climate variability through its influence on radiative forcing, cloud properties, and precipitation. Additionally, dust deposition can drive primary productivity and subsequent drawdown of atmospheric carbon by providing nutrients to ecosystems. Inputs of Australian dust may be especially critical in the nutrient-limited ecosystems of the South Pacific Southern Ocean and subantarctic islands. This study seeks to understand dust flux to Macquarie Island and the potential response of plants to changing dust inputs. Our high-resolution palaeodust flux reconstruction is the first from Macquarie Island peat and provides insight into dust transport in the South Pacific Southern Ocean through the mid-Holocene.

We selected a 290 cm peat core collected from the North Head of Macquarie Island, as peat plants can effectively capture dust and preserve the dust signal in the peat column. Data from ^{210}Pb and radiocarbon dating techniques, with additional age-control provided by the anthropogenic ^{239,240}Pu peak, inform the Bayesian age-depth model created using rPlum. Peat accumulation rates vary through the core, with the deepest 70 cm of core, 5247 to 4295 calibrated years before Present (cal. yr BP), showing the highest accumulation rate, 0.07 cm yr^{-1}, indicating that Macquarie Island may have experienced a mid-Holocene warm period.

We reconstructed the flux of long-range mineral dust with elemental data from x-ray fluorescence (XRF) and inductively coupled plasma mass spectrometry (ICP-MS). Dust flux is indicated by excursions in the XRF ratio of aluminium to titanium, which rises significantly above the median seven times through the core, four times from 3000 to 4600 cal. yr BP, and three times in the most recent 800 years. Al/Ti remains high for 20-60 years before returning to baseline conditions, possibly indicating changes in regional synoptic conditions. Additionally, high Al/Ti occurs concurrently with a high percentage of organic content, found by igniting sub-samples at 500 °C overnight. The correlation between dust inputs and organic content may indicate an enhanced biological response to nutrients provided by dust or changes in peat decomposition. We use Fourier-transform infrared spectroscopy (FTIR) to characterise organic matter decomposition and elucidate the effects of dust input in the peat archive.

Atmospheric dust variability over the last 3000 years inferred from an ombrotrophic peatland in southwestern Patagonia

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Peat bogs are remarkable paleoclimatic archives in the sense that they record past environmental and climatic change in terrestrial regions that are usually lacking in paleoclimatic reconstructions. They are, however, usually limited to the Holocene, as most wetlands began forming during or after the last deglaciation. In addition, the reconstruction of past climatic changes is complicated by the transition from ombrotrophic to minerotrophic sections, which limits the interpretation of the lower and older sections of retrieved peat cores. However, the abundance of organic material allows well constrained age models, and paleoclimatic proxy variability in the ombrotrophic section is usually thought to be representative of atmospheric changes. In peat cores, dust concentrations can be calculated using the measurement geochemical element concentrations, while dust sizes can be measured by analyzing grain sizes of the inorganic material. Such measurements allow inferences on the variability of past atmospheric dust concentrations, and indirectly on wind, precipitation, and general paleoenvironmental changes. Here, we present the paleodust deposition record from the upper 150 cm of a peat core from Rio Rubens, located in Patagonia in Southern Chile. The section comprises an ombrothrophic section of 100 cm. We present elemental and total mass dust deposition fluxes over the past 3000 years, and describe centennial and millennial variability in the record. We compare our results with centennial and millennial scale variability recorded in pollen data from other sites in the region, and highlight links with previously defined SAM-like multicentennial phases, and recent anthropogenic influence. We complement our multiproxy regional analysis with dust grain size analyses from the same core, obtained by calibrating a multilinear model using elemental concentrations as predictors.

Examining dust emissions from Australia’s largest lake, Kati Thanda-Lake Eyre (KT-LE) over the past glacial cycle: Do net-deflation events represent the largest dust pulses and has dust export reshaped the bathymetry of KT-LE over the last glacial cycle?

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Globally dust ‘hot spots’, individual geomorphic settings, such ephemeral lakes, represent the largest dust sources. In Australia, the lower Kati Thanda-Lake Eyre (KT-LE) Basin, including KT-LE itself, is the major contemporary dust source. Distal records, downwind of Australia, show high variability in dust flux over the past 35 kyr, ascribed largely to hydro-climate variability (Marx et al., 2018, 2022). Palaeo-shorelines at KT-LE indicate pronounced variability over the past glacial cycle, particularly after 48 ka when the lake dramatically dried (Cohen et al., 2015). Dry periods, interpreted from lake-proximal deposits, have previously been linked to net-dust deflation events (major dust emission episodes), potentially altering the bathymetry of KT-LE (Magee et al., 1995). Recent detailed revaluation of the iconic Williams Point sequence allows net-dust deflation events to be re-examined (Cohen et al., 2022). Redating provides little clear support for net-dust deflation events before the last glacial cycle. However, exposure of lacustrine sediment in cliffs above the modern playa floor and deposition of a lake-proximal aeolian unit (the Williams Point Aeolian Unit) imply a major net-dust deflation event sometime after 50 ka. Critically, this event is not recorded in distal dust records. By contrast, a later dust episode, broadly coinciding with (although extending beyond) the Last Glacial Maximum (LGM), is recorded in both distal and proximal records. Overall, it remains unclear if either event resulted in widespread surface lowering at KT-LE and the jury is out as to whether KT-LE experienced transformative net-deflation events. Similarly, it remains uncertain whether KT-LE operated as a dust hotspot before the LGM/Holocene, with results implying a wider landscape contribution is required to produce Australia’s largest dust pulses (Marx et al., 2022).

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Abrupt changes in dust provenance to the North African desert margin during the Holocene

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The North African desert margin is under the influence of the dry Saharan and the wet Atlantic and Mediterranean air masses. It is one of the areas most sensitive to the ongoing climate change. Models predict a decrease of precipitation leading to hyper-aridity. However, uncertainties remain large with a predicted precipitation decrease ranging from -4.5 to -22.9% for the latest CMIP6 simulations. Better reconstructions and understanding of the mechanisms that drove past changes of air-mass trajectories under the Holocene warm conditions could help reduce these uncertainties.

We present new data from a sediment core recovered from Lake Sidi Ali (Middle Atlas, Morocco) aiming at reconstructing variations in dust provenance using radiogenic isotopes (Lead (Pb), Neodymium (Nd), and Strontium (Sr)) on the <10µm detrital fraction of the sediment. The Pb, Nd and Sr isotopic compositions variations are coherent over the Holocene. In particular, there is a marked variation centered around 8.2 ka. Between ca. 7.5 and 4.5 ka the Nd (Pb and Sr) isotope ratios decrease (increase), then values are more stable. Using the radiogenic isotopes, we show that local inputs from the recent and highly erodible Moroccan volcanism are negligible in the fine fraction of the sediment. We also show that, although considered a major North African dust source, the Bodélé depression does not contribute to the Sidi Ali lake area. We have identified three potential dust contributors: the distal Mauritania-Senegal and the Southern Algeria-Northern Mali areas, and the more proximal Moroccan Atlas surface sediments.

The 8.2 ka abrupt event has been identified in numerous climate archives. At Lake Sidi Ali oxygen isotopes of ostracod valves and *Cedrus* pollen records both show significant changes around this event and have been attributed to enhanced spring rains compared to that of winter and cooler summers. The new radiogenic isotopes records show that a change in either dust provenance and/or the relative contribution of dust sources occurred at the same time. Hence, these results show that an abrupt change in air-mass circulation over the North African desert margin occurred around 8.2 ka.

The AO driven climate change from 3 ka to 2 ka detected by an 8000-year record of dust deposition in Lake Motosu, Mt. Fuji

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East Asia is a major source region for dust emissions. According to the average of 15 aerosol models, dust emissions from East Asia (330 Tg yr^{-1}) is equivalent to approximately 20% of the global total (1800 Tg yr^{-1}). Clarification of past dust transport can highlight variations in Westerly wind strength and pathway, as well as in source region aridity. However, reconstructing past dust transport in East Asia is complicated by several factors. The low sedimentation rate in the Northwest Pacific (<1 cm/1000 yr) is inappropriate for millennial- to centennial-scale studies, and distinguishing aeolian and riverine sources in coastal settings is challenging. While previous work used quartz physical properties to successfully separate the two signals, the obtained record is subject to relatively high chronological uncertainty.

Here, we use quantitative X-ray diffraction to determine quartz percentage, while leveraging the favorable conditions of Lake Motosu, to present the first chronologically well-constrained, high resolution dust transport record from the Pacific sector of Japan. Because the extremely small catchment provides no local source of quartz particles to Lake Motosu sediments, the record reflects East Asian dust transport, and with a ~0.5 mm/yr sedimentation rate, the high-quality age model is capable of resolving perhaps even decadal-scale deposition variability.

Despite the relatively stable Holocene climate, the Lake Motosu dust record reveals variable transport processes during the past 8000 years. Specifically, the amount of dust deposition is reduced from 3 to 2 ka. This low dust deposition event corresponds to elevated sea surface temperature in the Japan Sea and negative Arctic Oscillation (AO) phase. This suggests that these changes are associated with weakened Westerlies and with less frequent dust storms in the source region driven by negative AO phase. Moreover, a negative AO from 3 ka to 2 ka was coupled with the decreased North Atlantic Oscillation phase, which is strongly related to AO. Thus, detected climate change in East Asia is potentially linked to hemispheric scale climate change.

Holocene Dust Deposition in the western and central Pyrenees: The Arxuri peatbog and the Marboré and Arrablo lakes records

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Recent events have evidenced that most African dust input in the Iberian Peninsula occurs as wet deposition with the highest deposition rates in the Pyrenees. We investigate the input of Saharan dust in the western and central Pyrenees during the Holocene with multiproxy analyses of sediment cores from the Arxuri peatbog (497 m asl, western Pyrenees) and high altitude Marboré (2612 m a.s.l.) and Arrablo (2960 m a.s.l.) lakes in the central Pyrenees. We hypothesize that Holocene warmer periods were dustier and, consequently, we can expect more African dust in our atmosphere in the next future. The Arxuri sequence is composed of two older lacustrine units from early to mid-Holocene (< 9.5 ka BP) and an upper peat unit deposited during the last 3500 years. The Marboré sequence is composed of finely laminated silts and spans the last 14.6 ka. The Arrablo Lake is a newly formed lake and the sediment sequence spans a few decades. We use geochemical ratios (e.g, Fe/Ti) as indicators of Saharan dust input.

The Arxuri and Marboré sequences are coherent with regional dust records pointing to lower dust deposition during the early Holocene followed by enhanced dustiness during the mid and late Holocene after the end of the African Humid Period (ca. 7 - 4.5 ka BP). In Arxuri, decreased Fe/Ti ratios occurred during the Late Antiquity Little Ice Age (6^{th}-7^{th} centuries) and were relatively higher during the Roman Period and the last millennium, particularly during some phases of the Little Ice Age (15th-19^{th} centuries). In Marboré, during the last 2000 years, periods with relatively higher Fe/Ti are broadly synchronous with warmer phases: Iberian, Late Roman (4^{th}-5^{th} centuries), Medieval Climate Anomaly (10^{th}-13^{th} centuries) and early transition to the Little Ice Age and Recent Global Warming (mid-19^{th} century). In Arrablo, geochemical ratios suggest a recent increase in dust delivery, coherent with documented increasing dust transport towards the Western Mediterranean since mid 20^{th} century.

More geochemical, isotopic and biological proxies at higher resolution are in progress to better identify the sources and the relation to warmer periods in the past.

Lessons from recent dust storms for the paleoenvironmental interpretation of aeolian dust deposits: meridional Saharan dust transport towards higher latitudes

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Lessons from recent dust storms for the paleoenvironmental interpretation of aeolian dust deposits: meridional Saharan dust transport towards higher latitudes
External dust addition to sedimentary sequences must be considered during paleoenvironmental reconstructions. However, delimiting areas of potential dust accumulation is quite problematic, but identifying the mineral dust particles and determining the extent of dust flux is even more difficult.
Here, we present some rather surprising results from recent long-range dust transport events, discussing the effects of current climate change and the issues of large dust particles.
In the context of paleoclimate reconstructions, it may be interesting to note that sometimes (1) much larger areas can be affected by dust deposition events; (2) not only the finest grain-size fractions are affected by dust addition (even >100 µm particles can travel several thousands of kilometres); and (3) the amount of dust deposited may be much larger than previously thought or indicated by numerical simulations.
Over the past decades, an increasing number of Saharan dust storm events have been identified across Europe, using satellite measurements and imagery, numerical simulation data, meteorological analyses, air mass back-trajectories and surface observations. Both the frequency and intensity of dust storm events have increased over the last decade.
Saharan dust reached the Carpathian Basin at least 250 times between 1979 and 2022. These episodes of intense dust deposition clearly showed the effect of the wavy jet stream patterns, leading to (1) extreme weather events and intense dust storms in the Atlas region and (2) increased atmospheric meridionality.
In order to identify such events, we started our research in Iceland, where we identified 15 Saharan dust storm events between 2008 and 2020, two of which were also surface sampled. Laboratory analyses of the sampled dust material revealed abundant quartz particles larger than 100 µm, indicating that large dust particles can sometimes travel thousands of kilometres. Similar research has been carried out in Finland, where we have also identified several (n>60) Saharan dust storm events from 1980 to 2022.
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Enhanced understanding of large-scale Upper Pleistocene climatic and ecosystem changes through new Central European loess archives

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Over the last glacial period North Atlantic climate forcing and variability is well documented in high resolution marine and ice core records. The propagation and impact of millennial to centennial-scale climate fluctuations (e.g., Dansgaard-Oeschger events) onto the European continent are still not fully understood as terrestrial archives may be discontinuous and lacked precise and independent age models for a long time. Thus, robust correlations with other archives and proxies of global climate and environmental changes often remain challenging.

In this context, Loess-Paleosol-Sequences (LPS) represent outstanding terrestrial archives. Given their polygenetic character, however, enhanced understanding of geomorphological and pedogenic processes involved in LPS formation, and of the interplay with changes in environmental conditions, is required to maximize correlation with other archives. When achieved, LPS allow high-resolution reconstruction of paleoclimate and palaeoenvironmental changes on different spatial and temporal scales.

This contribution focuses on the Schwalbenberg LPS located in the Rhineland in western Central Europe, which provides one of the most complete, high-resolution record spanning the Last Glacial Cycle. Along a transect from the interfluve position to the foot slope we combined geophysical exploration with Direct Push geophysical measurements, sediment coring and sampling along exposed profile sections. Sedimentological and geochemical parameters are used to detect palaeoenvironmental and palaeoclimatic signals, allowing for a synthetic stratigraphic formation model for all Schwalbenberg LPS. We show that the transect approach allows quantification of different formation phases, whether accumulative, erosive or pedogenic in character. For the time interval from c. 80-15 ka correlation of combined lithostratigraphic features and organic carbon contents from Schwalbenberg with the Sofular and NGRIP δ^{18}O-records can be established at millennial to centennial scale resolution. In addition, high-resolution radiocarbon dating of earthworm calcite granules is used to refine and consolidate the Schwalbenberg LPS age model over the period ~ 50-20 cal kBP, independent from time-scales of other archives that the Schwalbenberg LPS can be correlated with.

Our results prove the sensitivity of western European LPS to Atlantic-driven climate oscillations in much more detail than in any other terrestrial archive known in the region so far and indicate large-scale synchronicity of detected climate signals.

The grain size of Pampean loess as a proxy of southern South American atmospheric circulation during the Last Glacial Maximum

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The Pampean loess is the most extensive terrestrial paleo-dust deposit in the Southern Hemisphere and a distinctive geological archive that records changes in past atmospheric circulation. Recent studies reported luminescence ages, mass accumulation rates (MAR), and Nd and Sr isotopic composition on three late Pleistocene-early Holocene Pampean loess sections (Lozada, Tortugas, and Gorina). These studies found a very mixed isotopic signal for the <44- and <5-µm fractions, dominated by a Puna-Altiplano Plateau (PAP) signal. Additionally, past investigations have reported a multi-modal grain size distribution on these loess sections.

To disentangle the origin of the Pampean loess multi-modal distribution, we report here a grain size unmixing analysis of bulk fraction, along with new Nd-Sr data for the >44-µm grain size fraction, on the late Pleistocene-early Holocene 2-m profiles of the Lozada and Tortugas sections. Unmixing methods allow differentiating three grain-size subpopulations/end members (EM) in the Pampean loess. EM1, only present in Tortugas, is composed of very fine silt and clay (mode = 5.7 µm) and has been associated with background dust transported from distant sources such as the PAP (~1300 km). EM2 is composed of fine silt (Lozada mode = 10.1 µm, Tortugas mode = 14.6 µm) and has also been previously associated with the PAP. EM3 is composed of a coarse-to-very-coarse silt fraction (Lozada mode = 48.8 µm, Tortugas mode = 49.5 µm) previously interpreted as a short-range-transported fraction associated with proximal sources (i.e., South-Central Western Argentina and/or Northern Patagonia).

In line with these interpretations, Nd-Sr isotopic data indicate Northern Patagonia and/or South-Central Western Argentina as the principal sources contributing to the >44-µm fraction (i.e., EM3) and the PAP as the dominant source contributing to the <44- and <5-µm fractions (i.e., EM2 and EM1, respectively). Our results indicate that the multi-modal grain-size distribution observed in Lozada and Tortugas loess sections originated at least partially from the contribution of multiple dust sources.

Further investigations should concentrate on understanding the temporal variability of the different source contributions and EM abundances, and their implications on the atmospheric circulation of southern South America.

Locally recycled late Pleistocene loess feeds modern dust storms at the desert margins of the eastern Mediterranean, Israel

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Current dust storms, originating from afar, are common in Israel and the eastern Mediterranean, and thus most dust sources are considered to be distal. However, recent studies suggest that the latest Quaternary loess accreted in the Northern Negev can also serve as a proximal source of dust. These sources were mostly neglected in past discussions as contributors of dust. Here, we demonstrate that such proximal dust sources, mostly the Negev loess, currently contribute relatively large amounts of recycled dust to the regional dust cycle. We conducted a sampling campaign of deposited dust during individual dust storms and identified high content of coarse silt grains and quartzo-feldspathic minerals within and adjacent to the Negev loess that gradually decreases

toward the north. These grains, characteristics of the Negev loess, indicate a short transport distance. In addition, our data reveal that local wind speed is the limiting factor for emitting proximal dust, regardless of the synoptic system. We determined that proximal sources in Israel emit dust during either local events or as a part of regional dust storms originating from afar. We evaluate the minimal contribution of this proximal dust to the total mass of deposited dust as 58–74%, 54–70%, 52–64%, and 26–34% for the northern Negev, central Negev, central mountainous region, and northern Israel, respectively. These estimates indicate that at the desert fringe, both proximal and distal sources of dust should be considered when inferring dust sources from dust geochemistry that can sometimes be similar due to the long dust history.

A New Approach to Dust Deposition Fluxes over the Southern Ocean from Seafloor Surface Sediments and Dust Grain Size

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Mineral dust is a major component of sediment input to the remote open ocean. About ten percent of all global dust emissions comes from Southern Hemisphere sources, and is important for (iron) fertilisation in the Southern Ocean. The main Southern Hemisphere sources include South America, southern Africa, Australia and New Zealand, but also inter-hemispheric transport from the Northern Hemisphere. In the South Atlantic, the majority of the total dust deposition originates from South American sources. However, in-situ measurements of dust deposition over the Southern Hemisphere oceans are scarce and there is a great need for an expanded geographical coverage of direct observations of dust deposition.

^{230}Th-normalised ^{232}Th deposition fluxes for lithogenic input are an important proxy for dust deposition. In areas with additional sources of lithogenic input, such as fluvial and hemipelagic sediments, ice-rafted debris (IRD), and (bottom)current-transported sediments, the lithogenic flux will be an overestimation of the dust flux. Here, we present grain size data and ^{230}Th-normalised ^{232}Th deposition fluxes of seafloor surface sediments covering the entire South Atlantic Ocean. By using end-member modelling we aim to disentangle the dust signal from these other sediment sources to reveal dust grain size. Combing the dust end members with the ^{230}Th-normalised ^{232}Th fluxes reveals the specific dust deposition fluxes to the South Atlantic. These more accurate dust fluxes show what dust sources are most important for different regions of the South Atlantic. We also apply this method to sediments from other regions of the Southern Ocean to investigate its general application of determining dust fluxes for open ocean sediments. As a result, the data produced will be valuable to calibrate and validate model simulations.

Provenancing terrigenous material in deep-sea sediment cores from offshore northwestern Western and South Australia, using on-land observations to understand XRF-scanned data

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It is common practice nowadays to assess the provenance of land-derived sediments (airborne dust, fluvial mud or ice-rafted debris) in sediment cores from marine, lacustrine and peat-bog environments using XRF scanning, but commonly very little is known about the transport modes or source(s) of these terrigenous sediments. In this presentation, we demonstrate an approach taken to geochemically fingerprint a large set of sediments collected from aeolian and fluvial sources in both southeastern Australia and northern West Australia to compare these data with records obtained from XRF scanning on long deep-sea sediment cores (MD03-2607, recovered south of Kangaroo Island and MD00-2361 recovered off northern Western Australia). In this approach, we successfully compare the chemical composition of source materials using XRF scanning of individual samples and records of XRF scanned sediment cores. In addition, we use trace elemental ratios obtained by ICP-MS and compare results for the same samples on which XRF analyses were conducted for the Kangaroo Island core. Finally, by sampling modern and palaeo-fluvial and aeolian sediments in the source areas of the sediment core off northern Western Australia, we can determine the sediment-transport mechanisms that brought the sediments out to sea in order to infer changes in palaeo-environmental and palaeoclimatic conditions in these source regions.
See: www.nioz.nl/dust

Session 36: Conservation paleobiology: late Neogene to Quaternary records as a baseline for conservation of modern ecosystems

Baseline Caribbean

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Caribbean coral reefs have changed dramatically in living memory, but it remains unclear if they have transitioned into functionally 'novel' states. We set out to address this question by using fossils to reconstruct reef states and functions before human impact. We mapped and sampled several hectares of mid-Holocene reefs in Caribbean Panama and the Dominican Republic and compared their composition and ecological function to nearby modern reefs. We quantified the remains of all major reef groups, but focus here on molluscs, corals and fishes. On modern reefs, filter feeding molluscs are twice as abundant relative to other feeding modes than on mid-Holocene reefs, commensurate with increased eutrophication from land use changes. At the same time, large herbivorous gastropods declined significantly in size due to millennia of human selective harvesting. The abundances of coral species in samples document the well-established loss of Acroporid corals, and functional analyses show a shift in dominance toward weedier, slower growing, and brooding species. Some modern coral communities appear to retain historical functional capacity, and isolated *Acropora* refugia do persist, but the corals in them are less robust than those in the mid-Holocene, questioning their functional resilience to future change. Numbers of otoliths in samples suggest an 80% decline in non-harvested fish and, of those remaining, planktotrophic fish species are now relatively more common—patterns best explained by the loss of coral structure and increased eutrophication. Otoliths also reveal that non-harvested fish assemblages on modern reefs are, on average, larger than they were in the past and experienced lower mortality rates, suggesting lower rates of predation due to a loss of predators. This conclusion is supported by the estimated 71% decline in shark abundances on the same reefs and a 400% increase in evidence of damselfish algal-gardening. These examples illustrate how both bottom-up and top-down processes have reshaped the structure, trophic interactions and ecosystem functions of Caribbean reefscapes. We discuss how these data can help answer if modern reefs exist in novel states and function in fundamentally different ways to those of the past, and what this means for the conservation of Caribbean coral reefs.

Ecological niche modeling of prominent Caribbean coral species

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Global warming and human impacts continue to be devastating for coral reef systems. In particular, Caribbean reefs have some of the poorest health ratings in the world. These reefs have been adversely affected by a variety of threats including elevated ocean temperatures, increased nutrient pollution, ocean acidification, and overfishing. To mitigate the effects of changing climates, it is vital to understand how ecologically important or prominent coral species in the Caribbean (i.e., *Acropora cervicornis, Acropora palmata, Agaricia agaricites, Colpophylia natans, Diploria labyrinthiformis, Pseudodiploria strigosa, Orbicella annularis, Siderastrea siderea*) are impacted by these threats. (Paleo)Ecological Niche Models were used to assess locations of suitable habitat for Caribbean coral species. Models from the Last Glacial Maximum, mid-Holocene, the modern ocean, and future projections were developed to determine which environmental variables are most important to these species, how niche occupancy changes, and how locations of suitable habitat shift over time. Utilizing the fossil record allowed this project to obtain a more complete picture of the coral's fundamental niche so better predictions could be made.

Mammal body mass as a community ecometric with utility for predicting future extinction risk

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Body mass is a fundamental functional trait across vertebrate groups, which influences diet, locomotion and thermoregulation. Within mammals, it is well established that mass varies across space, both within and across species. For example, body mass increases in cooler climates. We used mammal body mass and geographic distribution data from the PHYLACINE database to assemble community body mass distributions for 51,873 global terrestrial mammal communities (~50km resolution) along with climate variables for each of these sampling points. We built linear models for mammal community species count and mass mean, standard deviation, maximum, minimum, range, skewness, and kurtosis vs. two climatic variables: Mean Annual Temperature (MAT) and Mean Annual Precipitation (MAP). We also compared these results to those obtained through generalised linear latent variable models (GLLVMs). These models include data on diet as well as body mass. In particular, we focused on South America, a continent where other approaches to paleoclimate reconstruction (e.g. dental ecometrics) are less well-understood.

We found that global models generally had a low predictive power, and whilst this was substantially improved by using continental models, the relative superior performance of GLLVMs suggests that this method better captures the functional differences between communities. We found that for both global models and in South America, the relationships were very sensitive to taxon choice. For example, we found a positive relationship between mean mass and temperature when bats are excluded, but a negative relationship between mean mass and temperature when bats are included. To demonstrate the ability of these models to predict paleoenvironments, we applied them to Quaternary localities across South America and tested their predictions against those made by other proxies. For spatially-explicit communities in South America, we tested how warming relative to modern temperatures is expected to shift mammal mass distributions, through extinction or range shifts on short time scales. Comparison of projected community statistics with modern communities (and projected future communities) highlights which functional groups within communities are vulnerable to extinction with changing climates.

Reconstructing millennial-scale variability in reef shark communities across the Isthmus of Panama

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Shark populations worldwide have declined steeply over the last half century, but the patterns of change vary across space. Long-term records of shark abundance are limited, making it challenging to determine how local environmental conditions (e.g., ocean productivity) influence natural variability in shark populations and the magnitude of change from pre-exploitation baselines. Here, we use shark scales (dermal denticles) preserved in coral reef sediments to reconstruct shark communities during the mid-Holocene (~4-7ka) and today on both coasts of the Isthmus of Panama. We then pair these denticle assemblage data with comparable records of primary productivity and fish abundance to explore energy flow to higher trophic levels in each region. Panama's coasts are dramatically different. The Tropical Eastern Pacific is a highly productive, dynamic system driven by seasonal upwelling with a long history of shark exploitation that continues today. The Caribbean coast, on the other hand, is oligotrophic and environmentally stable, with much lower rates of harvesting. We find that denticle accumulation rates, a proxy for shark abundance, are an order of magnitude greater on reefs in Pacific Panama (Gulf of Panama) than those in Caribbean Panama (Bocas del Toro). Primary productivity and fish (prey) productivity are also substantially higher in Pacific Panama, helping to support this high predator abundance. Comparing patterns over time, denticle accumulation rates declined by 71% since the mid-Holocene on reefs in Caribbean Panama, including a selective loss of fast-swimming apex and mesopredatory pelagic sharks (e.g., families Carcharhinidae and Sphyrnidae). In sharp contrast, modern denticle accumulation rates in Pacific Panama are comparable to their range of variability during the mid-Holocene, and the functional composition of denticle assemblages remained similar through time—suggesting that the shark community in the Gulf of Panama has persisted despite intensive fishing activity. We postulate that the region's high productivity might underlie its high shark abundance and apparent resilience by increasing available resources for predators. Our preliminary findings provide insight into the role of energy in shaping natural variability in reef shark baselines and recovery potential in the face of ongoing overfishing. They also highlight the importance of incorporating oceanographic context into shark management.

Reconstructing Holocene changes in body size of Adriatic gobies using coupled radiocarbon dating and sclerochronological analyses of fossil and modern otoliths

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Climate warming is expected to lead to a reduction in the body size of marine organisms, a trend already observed in commercial fishes, but the effects of temperature rise on size distribution in exploited populations are difficult to separate from the impact of overfishing and other anthropogenic stressors. We aim to test the hypothesis that fish body sizes, as well as growth rates changed during the late Holocene and Anthropocene in the northern Adriatic Sea due to environmental perturbations caused by climate warming. We perform sclerochronological analysis on modern otoliths from modern fish, as well as radiocarbon-dated fossil otoliths of non-commercial, demersal gobies (*Gobius niger* Linnaeus, 1758) sampled from a sediment core taken off Piran (Slovenia) to quantify changes in body size and growth parameters throughout the Holocene. Otoliths are the aragonitic structures of the fish' inner ear with species-specific morphology, and thanks to their incremental growth, they serve as unique environmental and life-history archive. Moreover, otolith size correlates with fish size. We use otoliths cut in half to perform both sclerochronology and radiocarbon dating, obtaining a high-resolution time series of changes in fish body size, growth dynamics and life history parameters. We employ backscatter electron (BSE) imaging and electron probe microanalysis (EPMA) to identify body sizes and growth dynamics, as well as to correlate their growth increments with climatic and other environmental parameters. The reconstructed changes in body size and growth rates of very common, non-commercial fish species over the last 7.000 years, can serve as an ecological baseline for evaluating the magnitude of ongoing temperature rise and future shifts in fish populations in response to global warming.

Changes in bivalve species richness in the Mediterranean area during the Plio-Pleistocene time-interval

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The Mediterranean Sea is a marine biodiversity hotspot. Such unordinary diversity is currently threatened by global warming that may impact marine communities and trophic relationships among organisms. To predict how and how much marine species are vulnerable to recent and future climate change it is necessary to investigate how past species reacted to environmental disturbance. In this study we used the fossil record of Mediterranean bivalves (more than 400 species) to analyse how species richness changed during the Plio-Pleistocene time frame, a period characterized by multiple waves of climatic-driven bivalve extinctions. Assembling a species level dataset, across the entire Mediterranean area, we measured changes in species richness across different palaeoenvironments (from the shoreface to the slope) and for different tiering and feeding categories, in order to verify if specific environmental conditions and mode of life played a role in terms of ecological resilience to climate disturbance. Ecosystem response was assessed in terms of species richness, species turnover, niche breadth, and geographical range size. We show a significant loss of biodiversity in the Mediterranean area after 3 million years, especially in shallow water environments, consistent with the onset of cooler and less constant climatic conditions. Our results suggest extinction waves mainly involved suspension feeders whereas environmental dynamics seem not to have affected deposit feeders. Eventually, although bivalve richness gradually decreased towards Pleistocene, this period has the higher proportion of species appearance. We hypothesize that this is due to the onset of Pleistocene climatic oscillations and the introduction of northern and southern guests.

The future of Mediterranean biodiversity in a warming planet

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The rate of warming of the Mediterranean Sea is among the highest globally. Warming is hitting particularly hard on the easternmost sectors where a massive climate-driven collapse of native biodiversity is ongoing. These new environmental conditions are more proper of a tropical sea and, indeed, hundreds of Indo-Pacific species introduced through the Suez Canal are here thriving. These two processes are changing considerably – and irreversibly – the taxonomic and functional composition of benthic assemblages. But what is now ahead of us? The Quaternary fossil record suggests that in some of the Pleistocene interglacials, also tropical species of West African origin entered the Mediterranean. Is thus a new wave of tropical species going to invade the basin? In this talk, I will i) summarize the biotic and abiotic properties of the Mediterranean Sea in the context of global warming, ii) show the extent of the current collapse of native biodiversity, iii) provide the results of our models on the suitability of the Mediterranean for tropical West African species and on connectivity along the northwestern African coastline, and iv) offer new perspectives on the conservation of Mediterranean biodiversity in a warming planet.

The past as a lens for biodiversity conservation on a dynamically changing planet

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Given the magnitude of projected climate change, we anticipate that ecosystems will shift across the landscape as they struggle to adapt. The restoration of certain habitat connections and natural areas will be critical to maintain biodiversity and ecosystem service going forward. However, it can be challenging to identify the most effective strategies to allow ecosystems to bounce forward in the face of impending change. To create an effective landscape network, we must first understand how plants and animals are anticipated to respond to changing climates. How will species need to shift their ranges as climate changes? To what extent will habitat fragmentation hinder this movement? And what species will be most impeded by human-impacted landscapes? We use the late Quaternary fossil record from the Neotoma database to begin to address these questions and suggest ways forward for prioritizing landscape connectivity strategies.

We find that plants respond dynamically to changing climates, exhibiting rapid turnover once temperature changes exceed 1.5°C/500 years. This turnover translates to high climate fidelity, with plants tracking climate 86% of the time. If we examine today's landscapes, we see that the potential for range movement is quite limited. Only 41% of natural areas in the contiguous United States exhibit climate connectivity with human-impacted lands preventing climate tracking for 25% of natural land areas. However, we can also find that not all species are equally inhibited by human-impacted lands. We find that about one third of common mammal species in North America shift the climates where they live to avoid human-impacted regions, but that one third actually expand into agricultural- and urban-associated climates.

By identifying which plants and animals most respond to changing climates, what their range dynamics will be going forward, and which are hindered by the expanding human footprint, we can identify the most important regions for conservation and what restoration objectives will facilitate this dynamically changing landscape. Past, large-scale responses are critical to inform these objectives.

Lost ranges of plant species in the past anticipate modern endangered biodiversity

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The palaeoecological community is frequently interested in studying past rates of spread of plant populations as a measure of their ability to survive predicted global warming but has much less experience in determining location, timing and extent of past-range losses of plant species, a topic that is equally important in terms of conservation of modern ecosystems. We compiled a worldwide database of published fossil records of pollen, stomata, plant macro-remains and ancient DNA (aDNA) over the last 30 ka documenting the last occurrences of plant taxa at regional, continental or worldwide scales. Records were restricted to those with a solid chronological control, located more than 25 km from the nearest modern population for macrofossils and stomata, or 100 km for those based solely on pollen. These records represent either species extinction or loss of populations of extant taxa.

Our study revealed widespread range losses of plant taxa across all latitudes, with the majority representing gymnosperms. Focusing on conifers, a group of plants with well understood distribution and conservation status, we found that past range losses often overlapped areas where species are endangered at present, suggesting that such areas have been prone to biodiversity loss through time. During phases of past rapid climate change, even areas that currently have low numbers of endangered species were affected by plant range losses, in some cases with disappearance of taxa from entire continents, islands or major geographic regions.

This global analysis of range loss of plant species raises several unexpected questions, including the apparent contrasting fate of gymnosperm versus angiosperm species, the high rate of range losses at middle-low latitudes, which are generally considered to be effective refuge areas for plant species, and the failure of several species to re-occupy their lost nearby ranges over time spans of thousands of years. It also shows that understanding the extent of past lost ranges at a regional/local scale, and the factors underlying them, may provide crucial information to assess the current vulnerability of threatened species.

Contributions of the study of continental Mediterranean Holocene fossil mollusc assemblages to the conservation of an endangered group

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In Quaternary studies, fossil land shells are usually studied to investigate past environments and climates across various spatial and temporal scales. Over the last ten years, new molluscan successions from northeastern Morocco and southern Spain have revealed a high diversity of land snail assemblages during the Holocene. Nowadays, the highly anthropized Mediterranean Basin is considered one of the most sensitive areas to landscape and biodiversity modification due to climate changes driven by human activities. As one of the most threatened invertebrate groups, many Mediterranean land snail species require major conservation measures to ensure their survival.

On the basis of new Moroccan and Spanish sequences (Aït Said ou Idder; Blirh; Oued Charef, Galera) and a review of the existing paleomalacology literature, we discuss the significance of Holocene molluscan records from a perspective of paleobiology conservation. Most of the sequences provide records from the Middle Holocene (8200 – 4200 Before Present) consisting of a rich hygrophile fauna as common components. *V. moulinsiana* and *V. angustior*, both protected species under the European Directive, occur regularly. *V. enniensis* is common in several Holocene sites, but has a current distribution limited in Spain and is unknown living in Morocco. Likewise, the occurrence of the endemic *O. aragonica* at Galera and Baides shows that this species had much larger populations and a wider distribution during the Holocene which support its endangered species status

Middle Holocene molluscan successions provide an historical perspective of the occurrence of hygrophilous species before aridification and increased human impact led to the disturbance and fragmentation of wetland habitats. Molluscan fossil records are an ideal temporal tool to better understand the parameters that have shaped today's biodiversity and to identify the most vulnerable taxa.

Paleolimnology Meets Ornithology: Using Lake and Pond Sediments to Address Key Conservation Issues

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Long-term data are critical to contextualize population declines and to establish best management approaches. However, for most species, monitoring data are sparse or simply non-existent, and thus it is difficult to assess population baselines or rates of decline. Here we summarize several studies where we have used a broad spectrum of landscape-scale paleoenvironmental approaches on dated lake sediment cores to examine decadal, centennial, and millennial-scale dynamics of bird species. For example, we reconstructed long-term changes from two of the world's largest colonies of vulnerable Leach's Storm-petrel (*Hydrobates leucorhous*) on Baccalieu Island (Newfoundland, Canada) and Grand Colombier Island (St. Pierre and Miquelon, France) using multi-proxy approaches (e.g. diatoms, invertebrates, pollen, fungal hyphae, elemental and stable isotope analyses, fossil pigments, and sterols and stanols). Our reconstructed populations, based on paleolimnological changes from seabird-derived nutrient and metal inputs preserved in dated lake sediments, corroborate the limited survey data that suggest a recent decline. However, the much longer temporal perspective offered by paleolimnological analyses demonstrates that the most recent colony, from ca. 700 CE to present-day, is substantially larger than any of the prior colonies of the past millennia. Similar sedimentary approaches are also being used to track long-term changes in water birds (such as cormorants and eider ducks). Paleolimnological techniques have the potential to provide a long-term context for the size and persistence of seabird populations, as well as their effects on local terrestrial environments, which can lead to more realistic conservation strategies, within the context of multiple stressors.

De-extinction of mammoth traits to aid Asian elephants and arctic environments

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The Pleistocene – Holocene transition resulted in immense ecological restructuring, primarily due to the combinatorial effects of glacial retreat and mass megafaunal extinctions. Previous work has shown that resulting Holocene environments are less biodiverse and less productive than their Pleistocene counterparts. Well considered rewilding efforts has successfully been employed to increase genetic and biological diversity, as well as allow a new long-term avenue for ecosystem remodeling and enrichment. Here we discuss how the paleontological record offers important genetic tools to adapt extant species to an increasingly anthropogenic world, through the example of engineering cold-adaptive traits in Asian elephants. We also discuss some of the potential challenges associated with modern de-extinction efforts and how they may be circumvented or addressed in the most ethical way possible. Our work highlights some of the potential positive roles tailored de-extinction and restorative biology approaches can have for ecological improvement, as well as offering an important refuge by adapting endangered species to new and less human-dense environments.

Ecomorphological and biogeochemical shifts in a late-Pleistocene to Anthropocene mesocarnivore community

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While North American fossil mammal history is dominated by large carnivores and prey, most mammalian carnivores today are small ("mesocarnivores"): a taxonomic transition that followed a combination of climatic change, megafaunal extinctions, and human disturbance at the end of the last Ice Age. Here, I evaluate response to these intersecting major impacts in a mesocarnivore assemblage spanning the last 55,000 years in southern California, USA. Excluding coyotes, the late-Pleistocene to Holocene Rancho La Brea (RLB) asphalt seeps in Los Angeles preserve five mesocarnivore species each represented by >=10 individuals: American badger (*Taxidea taxus*), bobcat (*Lynx rufus*), grey fox (*Urocyon cinereoargenteus*), striped skunk (*Mephitis mephitis*), and long-tailed weasel (*Mustela frenata*). While these five species continue to populate the area today, radiocarbon dates indicate that not all species inhabited RLB at the same time. Rather, almost all fossil specimens of bobcats, grey foxes, and striped skunks date from before the Last Glacial Maximum (LGM), with badgers largely a latest Pleistocene addition. No sampled mesocarnivore specimens date to the LGM itself, likely an effect of low sample size or taphonomy. In multiple ecologically relevant linear traits, RLB specimens differ significantly from historic (<100 years old) representatives of the same species from the same geographic area. Fossil mesocarnivores were generally larger—decreasing in body size toward the present by as much as 27%—and exhibited a greater degree of carnivory-adapted morphology, perhaps due to competition presented by now-extinct megafaunal predators. Species-specific differences in postcranial morphology highlight shifts in locomotor ability, potentially recording responses to environmental change. Further, stable isotope analyses of carbon and nitrogen show differences independent of taxonomic turnover, although to what extent these differences reflect changes in diet rather than environment is currently uncertain. All species except the weasel demonstrate higher-on-average and more variable δ13C toward the modern-day than pre-LGM; the striped skunk & grey fox also exhibit lower-on-average δ13N in the Holocene to Anthropocene than pre-LGM. Leveraging biogeochemical and ecomorphological techniques, this multi-proxy study provides complementary metrics for diet and resource use, illuminating the roots of today's mesocarnivore fauna in the last Ice Age and highlighting their potential responses to continuing anthropogenic change.

Using geohistorical records to inform urban greening in a biodiverse megacity

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In a rapidly changing world, scientists and conservationists are increasingly leveraging fossils and other geohistorical records to inform restoration and management of global ecosystems, but these tools are rarely applied in human-modified landscapes. The ability of city planners and conservation biologists to respond to the challenges of the Anthropocene can be enhanced by incorporating local and regional geological, fossil, and historical collections, which can give insight into organisms' ecological flexibility, baselines for ecosystem structure and function, and correlates of extinction risk. While often thought of as connoting the erasure of natural baselines, cities can in fact possess rich records of pre-Anthropocene ecosystem states, including historic specimens and documents collected during the development of the city, and fossils and geological data unearthed during the construction of buildings, transportation corridors, and hydrologic conduits.

Los Angeles (California, USA) is home to 19 million people and located within the Californian Floristic Province, a biodiversity hotspot and one of the most floristically diverse regions in the world. A megacity with ambitious sustainability goals, Los Angeles embodies the tensions that city planners and conservation practitioners must navigate in balancing conservation priorities and human needs in populated landscapes. Access to green space is crucial to human well-being, and even minor botanical interventions in urban landscapes, like trees on city streets, have been demonstrated to help foster biodiversity. Understanding ecosystem structure, function, and resilience across periods of Quaternary environmental change in this region can be vital to creating sustainable green spaces in the context of ongoing global change.

Here we report on an ongoing collaboration between paleobiologists, urban ecologists, city planners, and conservation organizations to assemble and analyze data on the vegetational history of the Los Angeles Basin to support efforts focused on greening and enhancing biodiversity in urban spaces in Los Angeles. These efforts aim to address a range of urban conservation concerns including urban cooling, storm water filtration, biodiversity, equitable access to green space, and habitat connectivity. Our framework focused on community involvement also provides local stakeholders with new tools to advocate for natural spaces that are meaningful to them.

Drivers of changing parasite-host interactions in the Quaternary

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Parasitism is one of the most common modes of life on Earth, with up to 40% of species described as parasitic. While parasites are often viewed solely in the context of human disease, they play an important regulatory role in modern ecosystems and should therefore be considered as part of the effort to conserve their hosts. Despite the modern prevalence of parasites, past shifts in parasite distribution and diversity remain underexplored due to their poor preservation potential in the fossil record. A thorough search of archaeoparasitological literature could potentially address this knowledge gap – these studies document resistant remains (e.g., eggs and cysts) and genetic traces of parasitic organisms found predominantly in vertebrate coprolites and thus provide a rich source of information of parasite occurrences at archaeological timescales. Some groups of parasites such as hookworms, whipworms and roundworms are dependent on temperature to complete their life cycle and are particularly well-represented in the literature rendering them the ideal target for investigating how parasite distribution has been affected by past environmental change. Understanding such shifts is crucial for predicting the evolution of parasite-host interactions in response to the rapidly changing climate of the modern day. In contrast to recent modelling studies suggesting that warmer climates might lead to low-latitude parasites invading temperate ecosystems, our preliminary analysis of more than 600 parasite occurrences across different localities revealed an opposite trend of parasites shifting to higher latitudes during colder periods of Quaternary. As the next step, we aim to assess the impact of climatic fluctuations on parasite diversity and distribution using modelling approaches to increase the temporal and spatial resolution of our dataset. We additionally plan to estimate how biases in preservation and sampling – such as the overrepresentation of European and American localities in our dataset – might affect our findings.

A new ordination technique quantifying ecospace occupation of Pleistocene, modern, and projected future communities

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Due to widespread human impacts on global ecosystems, terrestrial vertebrate communities today are depauperate in many functional groups. To answer the pressing questions of which of these communities will be resilient through rapid environmental change, we can turn to the fossil record for a larger sample of communities structured without excessive influence by humans. Here, we summarize the structure of terrestrial mammal communities in terms of how they are composed of diet and body mass categories. Focusing on Eurasia, we show how modern mammal communities differ from the communities present at Pleistocene fossil sites and examine how projected future extinctions will shift occupation in this ecospace. Our modern data consists of global communities sampled based on range maps and species' mass estimates and dietary categories in the PHYLACINE database. We used Generalized Linear Latent Variable Models to reduce the dimensionality of variation between communities in the abundances of mammals falling within 18 body mass/diet categories (i.e. herbivores, carnivores, omnivores, invertivores). These models reveal structural differences in community composition between modern biogeographic realms.

We then analyzed how past, present, and future Eurasian mammal communities differ, using distance in latent variable (LV) ordination space as a metric for community composition change. We drew Pleistocene mammal occurrence data for Eurasia from the NOW database of fossil mammals. To address low sampling at some sites, we used recommender system modelling to estimate community composition at these sites based on associations between genera across sites in the database. We compared the input and output communities of these models with modern communities from the same regions, evaluating how the recommender systems reconstruct community structures. Finally, we estimated future communities by excluding species categorized as at-risk by IUCN assessments. Plotting these communities in LV space reveals which future extinctions re-structure communities into non-analog compositions outside of the range of LV space occupied by modern or Pleistocene communities. Models for large herbivores exhibit the greatest shift in LV scores with future extinctions. This methodology can be used in future to evaluate how extinction and conservation scenarios maintain or alter the functional composition of communities.

Past, present and future of Baltic Sea phytoplankton

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Climate Change and human impact have led to a profound decrease in marine biodiversity, particularly during the past decades. In the Baltic Sea, for instance, species composition of the phytoplankton primary producer communities has changed, affecting the food web and function of the marine ecosystem. Yet, the Baltic Sea underwent previous changes in its climate with alternating phases of increasing and decreasing temperature, salinity and nutrient conditions and additionally, an ongoing increasing anthropogenic influence.

Some phytoplankton species form resistant resting stages, which settle to the sea floor after annual blooms and can survive there for decades and centuries, particularly under anoxic conditions. Accumulating in distinct temporal sediment layers over years, they build up archives of temporal populations. Resurrected resting stages from respective sediment core samples can be used to study responses – specifically trait changes and adaptation of phytoplankton to environmental changes.

In this study we used Baltic Sea sediment cores and resurrection approaches to establish strains of ancient and recent populations of two common phytoplankton spring-bloom species, the diatom *Skeletonema marinoi* and dinoflagellate *Apocalathium malmogiense.*

We successfully resurrected strains, especially of *S. marinoi*, through different warm and cold periods of the Holocene, such as mid Holocene warm (~ 7000 years ago) and cold period (~ 3000 years ago), the warm medieval climate anomaly (~ 800 years ago), the end of the last little ice age (~ 170 years ago) and from the last recent decades, representing different anthropogenic affected periods.

To see how the historic and more recent strains respond to past and future climate scenarios and to establish and compare reaction norms, we conduct growth experiments under different temperatures and salinity levels and examine further traits like cell size, cellular nutrient ratios, stress and interaction. First results suggest a better growth of more ancient strains under higher temperature, assumingly in accordance with their habitual ambient temperature.

Together, this can help to understand the adaption of phytoplankton to increasing water temperatures and nutrients levels and to suggest their reaction to future climate scenarios. Further, this data can be used for management approaches.

Ecological niche modeling and distribution of planktic foraminifera from the Pliocene to the Anthropocene Epoch

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Although current anthropogenic climate change and biodiversity crises are unprecedented throughout geological time, lessons from past climate shifts can provide important information. Specifically, deciphering patterns, drivers, and biological responses across episodes of climate change in the past may constrain our understanding of extinction and survival risks associated with projected future ecosystem restructuring. During the last ~4 Ma years, the Earth System has experienced numerous glacial-interglacial cycles, providing an opportunity to deepen our understanding of how marine organisms responded to these different climate states.

Planktic foraminifera exhibit biodiversity patterns comparable with many marine trophic resources fundamental to humankind and have the most complete species-level fossil record of any known phylogenetic group. Here we investigate the exceptional record of extant and extinct species of planktic foraminifera using the Triton database from the Pliocene to the Anthropocene, applying ecological niche modeling and other quantitative methods to determine ecological responses, extinction, and survival risks for foraminifera during glacial-interglacial cycles.

Our preliminary results show that the biogeographic ranges of extant foraminifera shifted towards higher latitudes during warm climate states and contracted during glacial intervals. In contrast, extinct species of planktic foraminifera did not show significant range shifts during both warming and cooling events. The biogeographic range shifts of extant species were closely correlated with a benthic foraminiferal $\delta^{18}O$ record, a proxy for temperature and ice volume, based on the Generalized Least Squares regression modelling. These results indicate that the global extant of ice sheets and ocean temperatures are primary environmental drivers of range shifts in extant species; however, amongst extinct species, atmospheric CO_2 was the most important driver, with higher CO_2 levels corresponding to greater biogeographic ranges. The last ~4 Ma years was characterized by significant changes in global ice volume. Thus, we hypothesize that extinct species lost their suitable habitat as ice sheet changes became more significant. Many modern extant species appear to have responded to changes in the $\delta^{18}O$ signal associated with ice sheet and temperature fluctuations, which may suggest they can react to future changes in ice sheet associated with anthropogenic warming.

Late Pleistocene trophic networks from central Chile: using the record from Tagua Tagua (34.4°S, 71.1°W) to understand the role of humans as an agent of environmental change.

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One of the methods for reconstructing past ecosystems is to use fossil and archaeological records in combination with elements of theoretical ecology to generate models that bring us closer to the understanding of past ecological processes and states. In this context, the archaeological and paleontological record from the Antiguo Lago de Tagua Tagua (ALTT, 34.4°S, 71.1°W) in central Chile represents a unique opportunity for reconstructing of past ecosystems. Here, excavations at three different sites (TT1, TT2, TT3) have revealed a rich faunal record going from ~13 to 6 kyr BP along with events of human occupation and exploitation of animal resources. The record covers moments of important environmental changes such as the glacial-interglacial transition, megafaunal extinctions, and human arrival. All these together present the opportunity to reconstruct complex ecological features during the Pleistocene-Holocene transition in central Chile, such as species interactions, human-fauna interactions, and ecosystem stability. The present work shows the reconstruction of trophic networks using the records from the ALTT. The aim is to reconstruct two moments: 1) prior to human arrival, where other species interact in a late-Pleistocene ecosystem, and 2) after humans arrived (~12.6 kyr BP) and establish trophic links with several species. Using published data for TT1, we established a vertebrate species richness of 28 taxa during the Pleistocene-Holocene transition, including extinct and extant taxa. Feeding relationships among different taxa were estimated from the literature. Trophic interactions between humans and other vertebrates were inferred from published taphonomy studies. Network models were developed and analyzed using the NetworkExtinction package in R. Prior to human arrival the network presents 31 nodes and 107 trophic interactions, which increases to 32 and 126 respectively once humans arrive. In the scenario with humans, network properties increase indicating an enhancement in network stability. Extinction analyses did not reveal any secondary extinction due to the arrival of humans. Nor do secondary extinctions occur when megafaunal extinctions are incorporated into the model. Given the simplicity of our results, we are working in incorporating interaction strength and changes in primary productivity into the models, to better assess the resilience of a more realistic ecological system.

Going back for the future: incorporating prehistoric fossil records of saiga antelope (Saiga tatarica, Linnaeus 1776) into habitat suitability models to inform future conservation actions

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Globally, biodiversity needs immediate and effective conservation action. Prioritising suitable areas for conservation requires detailed knowledge of species-environment relationships. However, many species have suffered human-induced range contraction and may no longer occupy the full breadth of environmental conditions they could inhabit. This is particularly problematic for habitat suitability models (HSMs), which relate georeferenced occurrence records with environment variables to predict probability of presence or habitat suitability. The outputs are used to inform conservation management decisions, such as identifying reintroduction sites and designing protected area networks. HSMs assume that a species' contemporary range reflects its full species-environment relationship and may consequently underestimate suitable habitat predictions, thereby misinforming and biasing conservation decisions. Incorporating historic (centuries-old) occurrence records partly reduces this bias, yet even these records are still subject to anthropogenic range modification. The inclusion of deeper-time Pleistocene fossil records into HSMs is an effective way to broaden understanding of species' ecological tolerances and environment relationships prior to extensive anthropogenic actions. Here, we used prehistoric fossil records of the critically endangered and evolutionary distinct saiga antelope (*Saiga tatarica*, L., 1776) from the Late Pleistocene, alongside historic and modern occurrence records, to model suitable habitat under current and future (2070) climate projections. The results found an underestimation of predicted suitable saiga habitat using modern and historic records alone. The addition of prehistoric fossil records increased suitable saiga habitat by 700% and 608%, under current and future climate projections respectively. Our results suggest the saiga is not a refugee species but is occupying only a portion of its environmental range, having suffered species-environment truncation. Overall, this study highlights the importance of incorporating prehistoric fossil records into HSMs, to reduce the effects of species-environment truncation and to better inform conservation management decisions.

Multiple extinction and distributional changes of dung beetles reveals a collateral ecosystem collapse in Pleistocene-Holocene boundary

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During the Pleistocene-Holocene boundary (P-H; ~16 to 11 k cal BP) the South American megafauna result drastically reduced in diversity. At least 83% of the large mammals result extinct, including all megaherbivores over 1000 kg. This extinction most likely triggers a series of co-extinction events on dependent-species or with which megafaunal interacted.

Dung beetles have formed close associations with multiple groups of vertebrates, including dinosaurs and mammals. However, the lack of fossils records or analogue interactions has made it difficult to link the extinction of megafauna with the extinction of these beetles during P-H boundary.

Here we analyzed Upper Pleistocene – Middle Holocene layers in southern Chilean (Pilauco site) to explore the changes in diversity and distribution of dung beetles. Additionally, we evaluate the relation between dung beetle fossils and megafaunal bone records. We found that several taxa of beetles result extinct at the end of Pleistocene, distributed on multiple taxonomic groups. This pattern was also recorded in predator beetles and facultative dung beetles. Additionally, we recorded that some extant taxa have a discrepancy between the fossil and the modern distributional records.

We found that both extinction and changes in distribution are related to extinct megaherbivores. Thus, the presence of mammal records changes the assemblage composition and increases the diversity of dung-related species. Moreover, when megafauna records are absent, the dung-related species decreases notoriously.

We suggest that the extinction of megafauna causes a collateral and multiple extinction of dung-dependent beetles. Thus, the collateral extinction affected in *cascade* to multiple trophic groups of beetles, resulting in a collapse of the dung-related organisms.

These findings could partly explain the notorious low diversity of modern dung beetle Chilean fauna. Finally, future management decisions based on dung beetles (e.g., agroecology) should consider the fossil diversity recorded in Pleistocene deposits.

Drivers of shallow molluscan biodiversity change in the Piacenzian-Gelasian of the southern North Sea Basin shows baseline resilience and thresholds of shallow marine biodiversity.

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Shallow marine ecosystems and biota world-wide are undergoing rapid and profound turnover as a result of direct and indirect human-mediated activity. Yet we have little understanding how these will permanently alter/damage the functioning of these ecosystems. Understanding drivers and recovery of marine communities during adverse conditions from the fossil record can provide insights into recovery potential (resilience) and thresholds for ecosystem collapse required to assess the severity and outlook of today's biodiversity crisis. Even though depositional/fossil time series can be hugely informative, within shallow marine settings they suffer from widespread reworking and mixing, as well as post-depositional degradation. Also the poor resolution of stratigraphic age constraints the use of time series. We need time series that are adequate to understand todays challenges. In this study we use unprecedented borehole records of Late Pliocene-Pleistocene marine mollusk communities from the southern North Sea Basin (SNSB) in order to document faunal turnover, decipher drivers of turnover and understand recovery of taxa, communities and ecosystem functions. Using stable isotope analyses we constrain time intervals to the glacial cycle. The Pliocene-Pleistocene transition coincides with increasingly severe glacials, the arrival of Pacific immigrant species as well as strong changes in sediment load in the SNSB. The high diverse and specialized Late Pliocene communities became replaced by low diverse more generalist communities with a large percentage of (descendants of) immigrant species. We show that the latter were already established in low numbers prior to disruption episodes and profited from, rather then drove turnover. Within the overall biodiversity decline repeated short episodes of turnover occurred related to the disappearance of clear water environments and severe cold glacials. Turnover rates were very high (over 80% of species could be replaced within single episodes). Biotic decline and response in successive crises periods provide important insights into vulnerability and capacity of individual taxa, ecological groups and communities to withstand and respond to adverse conditions. Hence our study provides important insights into natural baseline dynamics and resilience of shallow marine communities in crisis periods relevant for the current Anthropocene Biodiversity crisis.

Session 37: Reconstructing Quaternary ice sheets

East Antarctic Ice sheet reconstruction inferred from geological evidence and glacial isostatic adjustment model

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Further understanding of the mechanism of Antarctic Ice Sheet (AIS) change requires the reconstruction of AIS variability over a wide range of timescales. Reconstructing ice sheets and sea level changes from geological data is useful for reconstructing changes on timescales over a few decades. East AIS is more stable and about ten times larger than West AIS. Recent studies indicate that part of East AIS melted during past warm periods (Crotti et al., 2022; Wilson et al., 2018). As in West Antarctica, where the ice loss is accelerating, a more detailed understanding of East AIS change is needed. However, the number and quality of geological data that cover the entire East Antarctic region are still sparse, and it is essential to utilize existing data and acquire new data.

As an example of research using existing data, this presentation will present constraints on AIS variability during the glacial period. The AIS has generally reached its maximum during the Last Glacial Maximum (LGM). However, there is insufficient data prior to the LGM to determine when the Antarctic ice sheet reached its maximum, which is largely uncertain. In East Antarctica, relative sea-level observations of about 30,000-50,000 years ago, corresponding to Marine Oxygen Isotope Stage 3, are available from lake and terrestrial sediments. However, there are deviations from the GIA model calculations, and the Antarctic ice sheet change history prior to LGM has not been fully constructed. Re-evaluation of the observations and reconsideration of the ice sheet history indicates that the Indian Ocean sector of East AIS has reached its maximum volume prior to the LGM.

Furthermore, we present the proceedings of the JARE geomorphological field surveys, aiming to reconstruct the East AIS changes from the Last Interglacial period. This field survey has sampled seamlessly shallow water, lake, and land-based sediments in Lützow-Holm Bay, East Antarctica. This talk will also present preliminary results on these sediments and the topographic survey, which is essential for deciding on coring sites.

Mud, boulders and bird vomit: constraining Antarctic ice sheet models

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Determining the past size of ice sheets matters for a range of reasons including understanding sea level contributions, the forcing mechanisms responsible for ice sheet change, and for correction of the satellite gravimetric data recording contemporary ice sheet mass balance that are affected by glacial isostatic adjustment (GIA). Work is ongoing to reduce the uncertainty in understanding of Antarctic Ice Sheet history and one key area for this work is the Coats Land-DML region of East Antarctica.
Here we report a multi-disciplinary study to improve our understanding of ice load history in this region. We report here on a programme of glacial geology, GPS and seismometer deployment, and modelling; all aimed at improving GIA corrections and thus reducing the uncertainties in ice sheet mass balance in a key region. We have mapped and sampled the glacial geological record of ice sheet fluctuations on a transect of nunatak sites stretching ~900 km from the Heimefrontfjella (74° 30'S) to the Whichaway nunataks (81° 30'). The glacial geomorphology is a consistent pattern of landforms and glacial deposits, which record a glacial (ice loading) history of the region that we have dated using two independent approaches of cosmogenic Be-10 surface exposure dating and by radiocarbon dating of stomach oil deposits (preserved stratigraphic deposits of proventricular stomach oil from snow petrels, *Pagodroma nivea*). The independent approaches provide remarkably consistent and complementary approaches to ice history and provides constraints for our ice sheet modelling.
We report an ensemble of continent-wide ice sheet models that are scored against geological data. Exploring the characteristics of the highest-scoring ensemble members highlights some key features of deglacial behaviour including a relatively narrow range of past excess ice volumes at the LGM, Holocene retreat behind present-day grounding lines with commensurate volume minima, and readvance behaviours. The comparison also allows us to identify areas where more geological data would have high constraining power for ice sheet models.

Southern limit of the Patagonian Ice Sheet

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The southern latitudinal limit of the Patagonian Ice Sheet at the Last Glacial Maximum is poorly constrained due to a paucity of field data. This particularly applies to southern outlet glaciers of the Cordillera Darwin Ice Field whose full extents have been debated by glacial geologists since 1899, affecting estimates of total ice volume. Here we report on the stratigraphy of exposed sections on the west coast of Isla Hermite which include glacial tills overlain by successions of peats and sandy silt. The location and orientation of the tills suggest that an ice lobe extended south from Cordillera Darwin across an extended Magellan outwash plain through Paso Mantellero and past Islas Hermite and Cabo de Hornos (Cape Horn). This was similar in extent to the Canal Beagle and Lago Fagnano Ice Lobes which extended to the east. Maximum extent occurred sometime before from 12880 cal. yr BP, and we discuss whether this is a close minimum age, or a product of delayed onset of peat accumulation at the sampling site. We provide a brief interpretation of the late Glacial and Holocene deposits overlying the till and from peat cores inland. These suggest peatland initiation before 15,400 cal. yr BP and the establishment of woody Magellanic moorland peat from 12880 cal. yr BP indicating a southward shift of the SHW during the early Holocene climate optimum.

Constraining the evolution of the Laurentide Ice Sheet through multiple glacial-interglacial cycles in central Canada

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The Hudson Bay Lowland (HBL) contains some of the most extensive depositional records of glacial and nonglacial events from inside the limits of the Laurentide Ice Sheet, including at least the last 3 glacial-interglacial cycles (MIS 2 to MIS 7+). The Quaternary stratigraphy in the western HBL has nonglacial units which have been correlated to contradictory marine isotope stages. There is a lack of reliable chronological constraints on both the glacial (typically till) and nonglacial units, leading to correlations based on elevation and superposition. Here, we present new optical ages and paleobotanical data constraining numerous intertill nonglacial sediments to the last interglaciation (MIS 5), including beds previously assigned to MIS 3. Furthermore, we document the fragmented nature of the stratigraphic record and show that MIS 7-aged nonglacial sediments are situated near the surface underlying one or two till(s) in some localities. The nonglacial beds, with age constraints and paleobotanical data, are then combined with detailed till stratigraphy studies to improve the regional stratigraphic framework. This provides insights into how the Laurentide Ice Sheet evolved across multiple glacial cycles. Our evidence shows that ice first advanced into the western HBL from the Quebec-Labrador dome during the onset of at least the last two glaciations. This suggests that growth of the Quebec-Labrador dome was more rapid, relative to the Keewatin dome, during the build-up phase of continental glaciations of North America.

Reconstructing the central sector of the Cordilleran Ice Sheet and readvance mountain glaciers in northern British Columbia during the Late Glacial

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The Cordilleran Ice Sheet (CIS) repeatedly covered western Canada during the Pleistocene and attained a volume and area similar to that of the present-day Greenland Ice Sheet at the Last Glacial Maximum (LGM). Glacial isostatic adjustment models indicate the rapid climate oscillations of the Late Glacial had a dramatic effect on CIS thickness, with abrupt Bølling-Allerød warming causing significant ice sheet thinning and ~50% mass loss. The subsequent cooling caused the expansion of alpine glaciers across the former central sector of the CIS, which is documented by the presence of readvance moraines. However, the mountainous terrain and remote location have thus far impeded our ability to collect the empirical evidence required to validate numerical ice sheet models and the configuration of the CIS during this period of rapid climate change remains enigmatic.

Here we use the glacial landform record to determine ice dynamics for the central sector of the CIS in northern British Columbia, Canada, beneath the LGM ice divide. Numerous high elevation meltwater channels indicate early emergence of mountain peaks and the orientation and distribution of other ice-contact glacial landforms, such as eskers, lateral and submarginal meltwater channels, kame terraces, and perched deltas, indicate active post-LGM ice retreat westward towards the Coast and Skeena mountains. We map the regional distribution of independent mountain glaciers, ice caps, and ice fields that regrew during a cooling event in the Late Glacial and show that some of these readvance glaciers were subsequently overrun by advancing outlet glaciers of the CIS. We use the cross-cutting relationship between readvance glaciers and CIS outlet glaciers, together with available chronological data, to reconstruct the eastern CIS margin during the Late Glacial for the first time. This provides new details on the deglacial dynamics that numerical ice sheet models might aim to replicate.

Paired cosmogenic isotopes reveal Early Pleistocene glacial history in northwest Greenland

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Long-lived cosmogenic nuclides in erratic boulders offer the opportunity to investigate pre-Last Glacial Maximum glacial history. In northwest Greenland, an expansive ice-free area between the Petermann and Humboldt Glaciers (Washington Land) preserves a record of Early Pleistocene glaciation in the form of cosmogenic isotopes that have accumulated in quartz-bearing erratic boulders. These erratic boulders were sourced from deep within Greenland's interior based on their lithologies, which do not outcrop in these locations today, and now litter the carbonate bedrock landscape. Here, we report paired measurements of ^{10}Be and ^{26}Al collected from the surface of 11 of these erratic boulders. These boulders have simple ^{10}Be and ^{26}Al exposure ages that are tens of thousands of years greater than the expected deglacial history based on existing radiocarbon and cosmogenic chronologies, and therefore contain inherited cosmogenic nuclides from prior exposures. The ^{26}Al/^{10}Be ratios from these boulders are 1.5-2x lower than a constant exposure history, revealing long periods of burial following past exposure. These low ^{26}Al/^{10}Be ratios require at least a 1.8 Myr history of burial during glacial periods and exposure during interglacials with ice smaller than present for 10s of kyr and larger for the majority of this period. The preservation of the boulders on the landscape also indicates that cold-based ice conditions have persisted in this sector of northern Greenland since the Early Pleistocene, which has implications for understanding the evolution of the Greenland Ice Sheet during the Pleistocene.

Saltmarsh records of recent mass balance changes in Greenland

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Saltmarshes provide excellent archives of relative sea-level (RSL) changes over a range of different timescales. In Greenland they yield precise RSL data over the past few decades to hundreds of years that can help constrain Greenland Ice Sheet mass changes during and after the Little Ice Age (LIA). They are particularly valuable as they provide a longer-term context upon which to evaluate recent tide gauge and GPS records which span only the past couple of decades.

This paper summarises more than a decade of work into fossil saltmarshes around the southwest and southeast margins of the Greenland Ice Sheet that record patterns of RSL change which indicate regional changes in the mass balance over the past few centuries. The data allows investigation into ongoing mass changes during and since the LIA and the timing of the end of the LIA in the climatically sensitive southwest and southeast portion of the ice sheet.

Microfossil (diatom) evidence from saltmarsh sediments at all studied locations record a recent change from RSL rise to stable RSL during the past 200 years. We interpret this change as evidence for the initial onset of mass loss locally from the Greenland Ice Sheet at the end of the Little Ice Age. We see no evidence for the recent accelerated GPS-recorded bedrock uplift around the coast of Greenland which we interpret as an extremely recent phenomenon. Geophysical modelling of the RSL data suggests that there are still things we do not understand about the response of the solid earth to changes in loading over decadal to centennial timescales.

This paper provides direct evidence that Greenland saltmarsh sediments can be used to reconstruct the timing of recent mass changes from marginal areas of the Greenland Ice Sheet, extending direct GPS observations back to the end of the Little Ice Age and beyond using geological data.

Network of lake records constrain deglaciation and Late Glacial expansion of the Iceland Ice Sheet

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During the Last Glacial Maximum, the Iceland Ice Sheet (IIS) extended out to the continental shelf edge, over 100 km offshore from the modern coastline. Following the collapse of the marine based sector (*c.* 14.5 ka BP), the 2 km thick ice sheet thinned and retreated to *c.* 40% of its volume, exposing widespread low elevation and coastal terrain. The subsequent regrowth of the IIS during the Late Glacial is constrained in several locations around Iceland, however, large uncertainties exist as to the timing, extent and thickness of the IIS during the Younger Dryas period as well as the rate and style of retreat during the Early Holocene. Here we introduce a network of well dated (radiocarbon) and tephrochronologically constrained lake records from around Iceland. Lake core basal ages limit Iceland´s glacial history during this dynamic transition into the Early Holocene and complement our current understanding of the deglaciation. Ultimately, new findings provide a more detailed history of the IIS as well as the response of marine-based ice sheets to changing climate and environment. Results will guide future glacier and glacio-isostatic adjustment models.

Submerged landscapes: uncovering the footprint of ice streaming in the Baltic Sea

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The southern sector of the Fennoscandian Ice Sheet occupied terrain that today is submerged by an epicontinental sea that penetrates into the heart of the ice sheet domain. The Baltic Sea catchment supported an ice sheet grounded well below sea level yet distant from the open ocean, and which, during deglaciation, terminated in a setting that was episodically (and spatially variably) a huge proglacial freshwater lake, a brackish sea, and/or near-shore subaerial terrain.

Compared to the present-day terrestrial areas surrounding the Baltic, extremely little is known of ice sheet flow and retreat through the submerged Baltic corridor. Rather, the palaeo-glaciology of the Baltic sector has been inferred based on the physiographic setting and implied from evidence in peripheral coastal zones. Yet, ideas of how the ice sheet behaved in the Baltic abound, from early ideas of rapid grounding line collapse to concepts of widespread ice streaming connecting to terrestrial lobate ice flow corridors along the whole southern margin of the ice sheet.

Recent and growing acquisition of seafloor bathymetric data from the Baltic opens up this ice sheet sector to interrogation for the first time. High-resolution terrain models reveal: i) the landform imprint of ice streaming and the dynamic evolution of stream pathways; ii) grounding line retreat that, in different sectors and at different times, has behaviour akin to the surrounding terrestrial sectors and to marine-based collapse; iii) a widespread and complex landform record of subglacial meltwater drainage; and iv) a strong influence of the underlying bedrock substrate on inscription of a glacial landform record. Here we present the footprint of ice streaming in, and deglaciation of, the Baltic catchment. We discuss its wider role in the deglaciation of the southern sector of the Fennoscandian Ice Sheet, and the styles, rates and potential drivers of behaviour in this shallow epicontinental setting.

Comparing the impact of input parameter sampling methods for sensitivity analysis when numerically modelling the last Eurasian Ice Sheet

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Numerical modelling of continental-scale palaeo-ice sheets can be computationally expensive given the large spatial and temporal scales involved. An ice sheet model requires parameter values to be chosen. Typically, many of these values are not precisely known. Unknown parameter values contribute to uncertainty in the model output, so understanding the effects of changing each of the model parameters is important. To incorporate the uncertainty in all of the model parameters, many model simulations would be needed to create a large ensemble. Instead, by conducting an initial sensitivity analysis, we can assess which parameters have the greatest impact on the ice sheet model output. Unimportant parameters may then be discounted from the ensemble, thus reducing the number of simulations required.

Here we compare multiple sensitivity analysis methods to decide which approach is most informative when conducting a small number of model simulations. Our model experiment of the Eurasian Ice Sheet accounts for 21 unknown parameters, which we sample in different ways. We start with a simple method of varying one parameter at a time to the extremities in each parameter's predetermined range. We then move to more complex statistical methods to investigate parameter interaction effects, by varying all parameters together and considering their dependencies. This work demonstrates the importance of parameter interactions when designing an ice sheet model ensemble.

Reconstructing deglaciation dynamics for the terrestrial margin of the last Irish Ice Sheet

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Reconstructions of the retreat of the last Irish Ice Sheet (c.21-14ka BP) provide important models for deglacial ice sheet behaviour, as the relatively small size of the ice sheet meant that it responded rapidly to shifts in atmospheric and ocean circulation. Recent mapping and dating of offshore retreat have shown the importance of marine-terminating margins and local topography in controlling the overall retreat rate. However, the pattern and dynamics of retreat of land-terminating margins of the ice sheet during the later stages of deglaciation are less well understood, for two reasons. Firstly, evidence for successive ice marginal positions is fragmented and the ice sheet configuration is not always clear. Secondly, while multiple dates exist to constrain the timing of ice recession offshore and along the Irish coastline, no absolute dates are available for the retreat across the central and northern lowlands. Consequently, attempts at modelling ice sheet configuration during later stages of the last deglaciation are poorly constrained by the physical record, leading to wide variation in proposed models.

We present new geomorphological mapping from high-resolution digital elevation models (1 m resolution), together with new ^{36}Cl terrestrial cosmogenic nuclide results from 18 limestone boulders from the central Irish Midlands, to reconstruct the regional pattern and timing of deglaciation. Larger glacial landforms in the area include drumlins and a large esker system, and the area was partly covered by a large ice-contact lake during deglaciation, Palaeolake Riada. A suite of previously undetected, low-amplitude landforms (mega-scale glacial lineations, crevasse-squeeze ridges and controlled moraine) indicates that the ice sheet was polythermal for at least part of deglaciation and also that surging occurred along the ice margin during deglaciation. The new results provide important new insights constraining for the first time the timing of ice margin retreat and proglacial lake drainage.

Investigating the controls on ice sheet dynamics: Insights from a new reconstruction of the land terminating sector of the last Scandinavian Ice Sheet

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The last Scandinavian Ice Sheet (SIS) offers a data-rich palaeo environment to study the processes controlling ice sheet dynamics. Theoretical and numerical modeling efforts investigating controls are greatly assisted by, and often require, ice sheet scale empirical reconstructions. The soft bedded, land-terminating maximum extent of the SIS (from Denmark to the Kola Peninsula) has seen spatially-varying levels of investigation using chronological, geomorphological and stratigraphic methods. It is difficult to synthesize and reconcile the range of differing methods and observations into a coherent sector-wide reconstruction. Here we present a spatially-consistent landform-based reconstruction of the entire land-terminating sector of the last SIS. Digital elevation models, a rapid symbolization mapping approach, and iterative testing of flow pattern scenario form the basis of our new reconstruction method. We briefly outline this empirical reconstruction method and the guiding 'rules' it uses. Our criteria for integrating the vast number of available dates with our retreat pattern reconstruction is outlined. This sector-wide reconstruction allows for the evaluation of hypothesized controls on dynamics. The reconstruction suggests a re-evaluation of ice divide organization is require to explain the observed flow geometries. We also discuss the importance of the growth and collapse of the marine sectors on land terminating ice margin dynamics and the SIS's interaction with neighboring Barents Sea and British Irish Ice Sheets.

Flow patterns of the Fennoscandian Ice Sheet derived from subglacial bedforms using high-resolution digital elevation models.

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Empirical reconstructions of palaeo-ice sheets, based on observations their landform records, are required to better understand ice sheet dynamics, and to improve numerical ice sheet models. We present a new reconstruction of the flow pattern evolution of the Fennoscandian Ice Sheet (FIS) from subglacial bedforms, exploiting the recent expansion in availability and coverage of very-high-resolution (1–2 m/pixel) digital elevation models (DEMs) over Finland, Sweden, and Norway.

Previous data-driven, ice-sheet-scale ice flow reconstructions of the FIS relied upon landform mapping from relatively coarse-resolution (decametre-scale) data, predominantly from satellite images and aerial photographs. Recently, however, 1–2 m/pixel LiDAR DEMs became available over Finland, Sweden, and Norway. They provide near-complete coverage of the ice sheet interior above contemporary sea level, and reveal additional complexity in the flow evolution of the FIS. However, this data richness and the size of the ice sheet domain amplify labour-intensity challenges of performing an ice-sheet-scale empirical reconstruction. We therefore applied a new, systematic multi-scale sampling approach for ice-sheet-scale mapping and flow pattern reconstruction, which overcomes the data-richness challenge while still providing informative data products for model-data comparisons.

We present new 'flowsets' for the FIS, which describe discrete ice sheet flow patterns and their relative timing. We also present the multi-scale mapping products we used to generate flowsets. This includes a map of >250 000 subglacial bedforms and bedform fields over Finland, Sweden, and Norway, and a map of 'landform linkages'. Landform linkages summarise the detailed landform mapping but do not extrapolate over large distances between observed landforms. They provide a reduced data product that is useful for regional-scale flow reconstruction and model-data comparisons, and remains closely tied to landform observations. Where relevant, we ascribe a relative chronology to overlapping flowsets based on landform cross-cutting relationships. Our flow pattern reconstruction over Finland, Norway, and Sweden is one ingredient of a reconstruction of the entire FIS within the ERC-funded 'PALGLAC' project (PI Prof Chris Clark).

Glaciodynamics of the Younger Dryas ice marginal zone in northwest Russia

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Previous reconstructions of Fennoscandian Ice sheet (FIS) glaciodynamics in northwest Russia during the Younger Dryas (YD) stadial are limited in scope owing to a lack of detailed empirical geomorphological and chronological data. As a result, previous reconstructions suggest the Kola Peninsula was glaciated by either the FIS, the Ponoy Ice Cap, or the Kara Sea Ice Sheet. In the neighbouring Republic of Karelia, the contrasting moraine assemblages are often grouped into alternative YD ice marginal zone (IMZ) scenarios. Utilising new databases of mapped glacial landforms and numerical ages, we present a new YD IMZ and early-Holocene (*c.* 12.9-11 ka) deglaciation reconstruction and investigate ice sheet dynamics of the FIS in northwest Russia.

Moraines and meltwater landforms are used to reconstruct IMZs and ice sheet retreat patterns in northwest Russia. The Tuloma IMZ extends the Norwegian 'Main sub-stage' moraines along the Murmansk Coast, with landform assemblages and topography suggesting that this ice margin was marine terminating. On the Kola Peninsula, extensive 'ring and ridge' hummocky moraine deposits were likely deposited by a cold-based ice margin readvance. Large cross-valley end moraines at the perimeter of the Khibiny Mountains also indicates that the FIS did not glaciate this massif during the YD. It is likely that the Kuusamo Ice Stream was active during the YD stadial; however, it is uncertain whether this extended as an ice lobe into the White Sea, or whether the ice stream was retreating. In the Republic of Karelia, six prominent and arcuate moraine and glaciofluvial outwash assemblages are interpreted as separate ice marginal zones attributed to independent ice margin readvance events. Abundant eskers and subglacial meltwater channels suggest that ice margin readvances in this region were associated with basal sliding. Available numerical ages indicate that the YD IMZ on the Kola Peninsula was established *c.* 12 ka, while the IMZs in the Republic of Karelia were deposited between *c.* 12.3 and 11 ka.

This new reconstruction provides a framework into which sedimentary and chronological reconstructions can be contrasted and compared, and crucial empirical data for validating numerical model simulations of the FIS.

Cosmogenic burial dating constrains the first major glaciations in the Western Alps

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Pleistocene glaciers descending from the Western Alps have repeatedly invaded the southern Alpine Foreland. At the Aosta Valley outlet, a spectacular set of arcuate ridges known as the Ivrea Morainic Amphitheatre contains one of the most complete sedimentary records of Pleistocene Alpine glaciation. Magnetostratigraphic analyses have attributed the timing of the earliest glacial advances to around the Brunhes-Matuyama geomagnetic reversal (~ 0.78 Ma), but this estimate is yet to be confirmed with absolute dating methods. Here, we target the earliest glaciations recorded at Ivrea by applying cosmogenic ^{26}Al/^{10}Be burial dating to the basal glacial unit, Mongrando, and an underlying preglacial fluvial unit, Muzzano. To the measured abundances of cosmogenic ^{26}Al and ^{10}Be, we apply the Monte Carlo-based inversion model, P-PINI, a burial dating method that specifically accommodates the low nuclide concentrations and non-steady erosion rates that are typical of glaciated landscapes. Our results resolve the timing of the first large-scale glaciations of the Western Alps at one of the classic sites of Quaternary geology.

What have we learnt about glaciology from palaeoglaciology?

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From valley glaciers to ice sheets, till deposition to Heinrich events, the practise of studying past ice masses (palaeoglaciology) has produced interesting avenues of research spanning scales from micro to global. Beyond being a fascinating intellectual curiosity to many, the potential that palaeo records have for informing about contemporary glacial processes and prospective future states of contemporary ice masses, is often touted as a justification for studying the past. Here we review the literature on palaeoglaciology to examine the extent to which this justification is true, asking what have we learned from palaeoglaciology? We review how palaeoglaciology was at the centre of the inception of glaciology in Europe, emphasising that knowledge passed down through generations about palaeoglacial events and locations meant that the indigenous peoples of glaciated regions have recorded palaeoglaciology for millennia. Since then, palaeoglaciology has continued to provide numerous insights for glaciologists, a few of which are mentioned here. One of the largest insights from palaeoglaciology was the realisation that ice sheets could rapidly change, as was revealed by Heinrich events. The accessible landscapes of deglaciated areas have provided insights into subglacial processes, for example revealing the architecture and evolution of subglacial hydrology over timescales beyond that of the current observational record. Hypothesising about one of the most abundant landforms found in deglaciated regions, drumlins, led to the idea of till deformation prior to it being considered in a contemporary setting. Recently, a greater integration of numerical models and palaeo-data has revealed a lag between the response of a glacier to climatic changes, and enabled the study of the marine ice sheet and ice cliff instabilities. Our review finishes by touching on how the palaeo-record may contribute to solving many of the puzzles facing glaciology today. Perhaps most importantly, projections of ice sheets and glaciers in our warming world, must account for historical conditions and hysteresis. Thus, perhaps unsurprisingly, we conclude that palaeoglaciology is more relevant than ever.

Session 38: Reconciling deformation through Geomorphology, Active tectonics and Paleoseismology investigations along the India plate

Active Transfer faulting in the Western Sub-Himalaya of India: Implications to seismic hazard assessment

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The Himalaya presents a complex tectonic deformation scenario with variable fault geometries in the sub-surface and wavering fault traces on the surface. In three dimensions this complexity tends to modulate the stress trajectories and therefore the style of faulting. Accordingly, non-Andersonian tectonic regimes could affect large crustal volumes and generate faults with oblique-slip kinematics, where both dip- and strike-slip components occur. Field observations from Western Sub-Himalaya of India allowed to recognise and record such complex faulting.

In particular, Remote Sensing of such complex deformation allows a bird's eye view of the landforms and is best suited to observe lateral motion which may otherwise not be observable in the field. We present a suite of geomorphic features such as offset drainage, abrupt truncation of streams, faulted basin geometries etc. to spatially locate the fault line. Subsequent detailed landform evaluation is employed to establish the sense and dimension of lateral motion.

Our examination suggests that the investigated landforms are consistent with left-lateral motion along an oblique fault across the Western Sub-Himalaya. It is inferred that in the context of fault geometry, such lateral motion is possible due to the obliquity of the identified fault. However, the fault line does not demonstrate any significant seismicity throughout the instrumental recordings. Of course such behavior of the fault may be a matter of different temporal scales of observations.

Therefore, in view of the active tectonic landforms the mechanism of fault slip is open for debate: whether it slips aseismically or seismically with a long-return period. In either case it may play a significant role in redistributing tectonic stresses which may have important implications to earthquake hazard in Sub-Himalaya.

Paleoseismic evidence of an 1100 CE earthquake along a blind frontal thrust segment in the Central Himalaya

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Paleoseismic studies along the 2500 km Himalayan arc have been able to locate several stretches where fault strands arising from the Main Frontal Thrust (MFT) during discrete seismic events have propagated into the recent alluvium cover of the Indo-Gangetic plains and caused folding and thrusting of the young sediment layers. Successive great earthquakes have been reported along the Himalayan front at 1344 CE, 1255 CE and 1100 CE that produced surface ruptures for lengths of >700 km on overlapping MFT segments. This study is aimed at carrying out paleoseismic investigations along a stretch of the Central Himalayan front, in order to determine the timing, and extent of past major earthquakes in the area. The study involves detailed mapping of the terraces followed by trenching along a frontal fold scrap near the Sofa temple site in Manguraha village of northern Bihar. Radiocarbon and OSL dating of the trench sediments was carried out to establish the trench stratigraphy. Trenching was carried out at the topographic break of a laterally extending elongated ridge that arises from the base of the Siwalik hills and resembles a fold topography. The trench section shows distinct folding of the sediment layers, but noticeable fault offsets are absent which led us to infer folding on a blind thrust. We explore various scenarios that produced the deformation at the Sofa temple site. The latest event in the Sofa temple trench is most likely related to the ~1100 CE earthquake that has been previously reported from trench sections in eastern Nepal, Bhutan and eastern India. Uncertainties in rupture length, width and slip are tested, based on which, the size of the ~1100 CE earthquake is inferred as Mw ~9 that produced surface deformation over a length of ~850 km between the central, east-central and eastern Himalaya. While co-seismic offsets associated with the event have been recorded at previous trench locations, the ~1100 CE earthquake failed to reach the surface in the present study area. Our study highlights on the need to investigate lateral heterogeneities in the Himalayan décollement that could lead to inconsistencies along the rupture plane.

New Paleoseismic Excavations Across the Main Frontal Thrust of the Himalaya at the Chor Ghalia Site in Northern India

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The Main Frontal Thrust (MFT) of the Himalaya orogenic convergence at the site of Chor Ghalia, located between Haldwani and Tanakpur in eastern Uttarakhand, India, forms a scarp along fluvial terraces of the Nankhaur River that are at heights of approximately 50 m, 25 m, and 7 m above the stream bed. The Nandhaur River crosses the MFT where a knickpoint marks the adjustment of the stream from the last scarp-forming event. Colonial-era waterworks which likely followed the Medieval aqueducts require a mechanism to drop the water over the fault scarp into the irrigation system of the terraced agricultural fields. In this study, we excavated 5 m-deep trenches across the MFT at the base of the high scarp where clear topographic inflections suggest scarp-forming events at the toe of the slope. In the footwall, the stratigraphic section contains basal boulder-cobble gravel and an upper muddy cobble-pebble gravel that is overlain by brown silty sand. This upper portion of the sand is darkened with organic material, contains potsherds, and is evidence of an anthropogenic surface. The hanging wall contains two stacked recumbent folds. The nose of the lower anticline runs far out over the anthropogenic surface in the footwall and is accommodated by the rotation of pebbles and cobbles. The upper fold is cut by an additional thrust. Two sequences of colluvium were mapped. The expression of deformation is similar to other sites along the MFT including LalDhang located about 150 km to the west. Samples were collected for dating from *in situ* burns on the footwall below the colluvium that post-dates the fold deformation and from the colluvium above the nose of the fold. Whereas the timing of these events awaits results of radiocarbon dating, the data from this study show that two major events likely ruptured this section of the MFT. Previous investigation of the site by Rajendran et al. (2018) suggests that the 1344 earthquake ruptured the site. As erosion has modified the scarp and colluvium contains remobilized organic material, it may be difficult to clearly define the timing of closely spaced historical earthquakes in the Medieval period.

Evidence for Active tectonism in tropical climatic zone: clues from Peninsular India

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Present tectonic regime of Peninsular India is compressional and damaging earthquakes usually occur at favorably oriented pre-existing weaker planes/faults. However, identifying neotectonic signatures from such a cratonic region especially Tropical (humid) climatic regions are very challenging due to its characteristic slow movement. Based on the paleo-continental position, Indian landmass was in favorable position for laterization since pre-Oligocene, thus the laterite could preserve deformation since Oligocene. The quest for identifying evidence from such a terrain has led us to identify features indicating deformation in the present compressional tectonic regime.

Our studies shows that any deformation occurred in vermicular laterite is brittle in nature. Continued leaching processes leads to sealing of these cracks by iron rich minerals like Goethite or Hematite up to the depth zone of oxidation in the form of veins. The cracks which appear fresh or does not hold any mineral precipitation indicate lack of time for leaching. Our studies in areas of reverse faulting indicate that the saprolite, acting as a décollement, deforms like semi-ductile or ductile and can produce folding, shear band boudins Reidel fractures and/or injunction of material upward into cracks in laterite like dykes. The emerging segments of reverse fault at lateritic top often show bulging and as well as antithetic movement in the hanging wall block. Our studies close to southern tip of peninsular India discovered several trapped aeolian deposits due to reverse faulting in vermicular laterite. These deformations are dated around 1.7 and 4.3 ka. In the areas of strike-slip fault zone, the movement appears reach the surface. Here presence or absence of saprolite does not makes much difference for deformation at the surface as the movement is confined to narrow zone. Intense crushing of laterite results in growth of vegetation along the trace of the fault. Geomorphology of the fault zones indicate controlled/deflected drainages and linear valleys along the fault zones.

The present hindrance for active fault evaluation is the scarcity of datable material for event bracketing. However, these clues will be touchstones for future studies in the field of active fault evaluation in such terrains.

Surface Deformation, Fault Model and Tectonics of the 22 June 2022 Afghanistan (SW of Khost) earthquake

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The Afghanistan earthquake of 22 June, 2022 was located about 150 km south of capital city of Kabul. It struck post-midnight in the SW of Khost town of Eastern Afghanistan. Almost 5000 lives were directly impacted where more than 1000 were reported dead and another 2000+ were injured. It also caused damage to houses either complete or partial. However, the actual ground deformation and source mechanisms could be only poorly constrained due to scanty field and instrument data. This is perhaps limited by the remote location and poor access to the affected areas. The Preliminary reports suggest that *the* earthquake event was predominantly strike-slip faulting, either left-lateral slip on a northeast-striking fault or right-lateral slip on a northwest-striking fault (USGS). Although this information is consistent with the larger tectonics of the western boundary of the India plate that corresponds with the Chaman Transform the details of actual surface deformation are lacking. The present scenario allows taking advantage of the remote sensing measurements, particularly Differential Interferometric Synthetic Aperture Radar (DInSAR) technique to pin-down the extent and nature of surface deformation. To this aim we investigate the surface deformations induced by the occurred seismic event by using DInSAR products generated from Sentinel-1 (S1) constellation SAR data, via the Parallel Small BAseline Subsets (P-SBAS) algorithm. In particular, we exploited the co-seismic interferograms and relevant displacement maps generated over ascending and descending orbits and available from the European Plate Observation System (EPOS) catalog. The processed S1 interferograms are characterized by 12-days temporal baseline, 18062022 – 30062022 S1 acquisitions for ascending orbits and 19062022 – 01072022 acquisitions for the descending ones. The DInSAR deformation results are inverted to determine a reliable fault model that could justify the co-seismic surface deformation, geology of the area and larger tectonic context of the earthquake. The importance of our study lies in, besides the humanitarian and economic concerns, its scientific value to understand the active tectonics, source mechanism and earthquake hazard of the western transform boundary.

How earthquake influence shallow aquifer system? Lessons learned from the coseismic liquefaction-induced deformation following the 2019 Mirpur earthquake, Pakistan

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The Mirpur city and surrounding villages were severely damaged by extensive coseismic liquefaction within 6 km of the epicentre of the Mw 5.8 Mirpur earthquake on 24 September 2019. The earthquake-induced coseismic deformation on the ground surface included sand blows, ground failure and lateral spreading, whereas subsurface coseismic signatures were observed in the form of elevated groundwater table, fractures, water-filled zones, sand dikes, and lenses of high conductivity. The geology of the study areas is dominated by the Quaternary alluvial deposits overlying a liquefied sandy soil. The inverted electrical resistivity models reveal three regional geoelectric layers having thickness ranging from 2 to 8 m characterized by resistivity values from about 25 Ωm to >100 Ωm. The fractures and elevated groundwater table were mapped on the resistivity and ground penetrating radar measurement (GPR) sections. The subsurface detection of sand dikes produced by transported liquified sand into the shallow subsurface layers and other liquefaction features (conductive clay pockets, and water enriched zones) provide unequivocal evidence of coseismic deformation/unstable ground conditions. Coseismic deformational patterns were found within the area of ground shaking intensity of VI where residential buildings and critical infrastructure (e.g., the Upper Jhelum Canal, bridges, and the main Jhelum–Jatlan road) were severely damaged. ERT and GPR surveys assisted in the reconstruction of these structural and hydrogeological features in the near-surface. Geophysical results were found in agreement with the field observations (sand blow, fissures etc.). Based on geophysical and geological measurements, we infer that the Mirpur earthquake-induced changes in the shallow aquifer system and associated deformation were primarily controlled by the local geological setting and groundwater table amongst other factors.

Crust and upper mantle velocity structure of India, Tibet and surrounding regions analysed using Rayleigh wave dispersion data of earthquakes.

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We model the 3D shear-wave velocity structure of crust and upper mantle of India, Himalaya, Tibet and surrounding regions. This highly resolved lithospheric velocity structure upto a depth of 200 km provides detailed understanding and improved clarity on key evolution and deformation aspects. The work provides holistic perspective on the Indo-Eurasian region highlighting three subduction zones, world's largest mountain range, several sedimentary basins, world's largest plateau system, and one major island group in context of their structure and the natural risk they possess with respect to earthquakes.

2D group velocity tomography maps, resolvable laterally at 3°, are produced from 1D event-raypath dispersion curve between 10-120 s. They provide first order insights about the high velocity persistent in cratons of the Peninsular Indian shield, Eastern Himalayan syntaxis, Pamir, Hindukush and other regions representing high grade metamorphic rocks. Similarly, the Mahanadi and Godavari rift, Bay of Bengal basin, Himalayan foreland basin, Afghan Tadjik basin, Makran subduction zone, and Andaman islands represent the sediment-laden low group velocity structures.

The shear-wave velocity (Vs) structure obtained by isotropic inversion is presented as depth sections and profiles to study its lateral variations across the entire region. Focal mechanisms of moderate-to-large earthquakes, Moho depth computed from Airy's isostatic compensation, free-air gravity anomaly data, petrological studies from previous works are investigated in-tandem and discussed with the Vs structure to unravel the tectonic evolution.

Salient insights include flexural bending, underthrusting of Indian plate till Altyn-Tagh fault in western Tibet and till Jiasha suture in central and eastern Tibet, crustal thickness of each tectonic unit, and sediment thickness of major sedimentary basins. Very high velocity in upper mantle region of Indian cratons, Tibet and Hindukush-Pamir is speculated to be due to eclogite facies rocks unlike the Deccan Volcanic Province and eastern Dharwar craton where this high velocity layer is absent, possibly due to plume volcanism related thermal anomaly or metasomatism.

The coherence between the convergence rate, deformation of topography, and the earthquake records discloses this regional scale velocity model as a baseline model that can be considered for disaster mitigation and research studies of local extent within the Indo-Eurasia region.

Archaeoseismology reveals intraplate seismicity – the Indian Peninsula

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Mountainous perimeter of the Indian subcontinent is seismically highly active, while the Peninsula is considered a stable region. Short instrumental record of earthquakes in India make it imperative to use historical and archaeological means to understand past seismic activity. While seismicity of the Himalayas is in the centre of attention of researchers, with a new dedicated monographic volume carrying valuable information, the Peninsula itself is much less studied. We review recently published data on various Hindu, Muslim and Portuguese monuments in Delhi, Konark (Odisha), Mahabalipuram (Tamil Nadu), and Diu, to illustrate the rich possibility of archaeoseismological research. Unknown earthquakes and tectonically raised coasts are identified. Destructive seismic activity is proven in sites considered to be of low seismicity. Deformed man-made structures can be evidence for earthquakes in deep time.

Session 40: The Anthropocene as a tool for characterizing recent planetary change and predicting future environmental challenges

A consideration of global stratigraphic markers for identifying the base of the proposed Anthropocene epoch in the mid-20th century

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Human activities on Earth have become so far-reaching, and the scale and extent of our impacts on biodiversity, biogeochemical cycles, Earth surface processes and climate so profound, that they have led to the proposal that a new geological time period (known as the Anthropocene Epoch) can be defined by this global human influence, starting in the mid-20th century. The process of defining a new epoch requires the identification of a globally synchronous stratigraphic marker for its start point, known as a Global boundary Stratotype Section and Point (GSSP) or 'golden spike'.

While a large number of potential markers have been considered across 12 candidate GSSP sections including radio- and stable isotopes, black carbon, fly-ash particles, organic pollutants, trace metals and microplastics, just a few have been shown to provide the synchroneity required across multiple natural archives. Here, we use data primarily from the Anthropocene GSSP investigations but also from other studies to consider just two of these: plutonium isotopes and spheroidal carbonaceous fly-ash particles (SCPs). We discuss why these markers are especially useful for the Anthropocene and show how records of globally distributed indicators (e.g., Pu) and records of indicators which are regionally distributed but still globally synchronous (e.g., SCPs) can both provide high resolution and reliable stratigraphic records for the new epoch. However, while the global increase in plutonium following the onset of high-yield thermonuclear weapons testing in 1952 is being considered as the main candidate for the primary marker of the Anthropocene, many other indicators also show considerable stratigraphic changes in the mid-20th century. Although the definition of a primary marker is required, ultimately it will be multiple indicators of the extraordinary human impact since the mid-20th century that will identify the new epoch in environmental archives across the world.

The Anthropocene record preserved in the annually laminated sediment succession of Crawford Lake, Ontario, Canada

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The varved sedimentary succession preserved in Crawford Lake, Ontario, Canada is one of 12 potential candidate sections to be selected as the Global boundary Stratotype Section and Point (GSSP) for the Anthropocene series/ epoch, with a proposed base in the mid 20th century. The sedimentary succession is comprised of seasonally deposited laminations of organic matter capped by calcite that is precipitated each summer in alkaline surface waters when pH and temperature exceed 7.76 and ~15°C respectively. The sedimentary record preserves diverse proxies that reflect environmental change at local to global scales that have been documented to characterize the beginning of the Anthropocene. The spheroidal carbonaceous particles and bulk sediment nitrogen isotope sequence records a significant increase in fossil fuel combustion in the early 1950s. Ratios of 239Pu:240Pu and 14C:12C both peak in the 1960s, coincident with an increase in radioactive fallout from thermonuclear testing; the latter more than compensating for the effects of old carbon in the dolomitic basin of Crawford Lake. The rapid industrial expansion in the North American Great Lakes region that occurred during, and particularly after, WWII, associated with what has come to be known as the Great Acceleration, led to enhanced leaching of terrigenous elements by acid precipitation. A reduction in calcite precipitation and low primary productivity produced thin calcite laminations coeval with the proposed GSSP. The relative thickness of laminations can be linked to the influence of trends and cycles in climate and lake productivity. Time series analysis identified cycles that are attributed to the Quasi-biennial Oscillation (2.3 years), El Nino-Southern Oscillation (2-7 years), the 11-year Schwabe sunspot cycle and Pacific Decadal Oscillation (50-70 years). The absence of fossil pigments from obligately anaerobic purple sulfur bacteria indicates the presence of an oxygenated monimolimnion with elevated bottom-water salinities being responsible for the preservation of varves. This inference is confirmed by water property data collected through the modern lake water column in all seasons. Such an aerobic depositional environment is unusual for a meromictic lake and serendipitously hindered the mobilization of 239Pu in the lake sediments, the proposed primary stratigraphic marker for the Anthropocene.

Dynamics of biotic and abiotic markers of the Anthropocene at Jasper Ridge Biological Preserve, California, USA

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Humans have been altering our planet throughout the Holocene, but the scale of impacts increased dramatically in the mid-20th century, representing the start of the proposed Anthropocene Epoch. These pervasive anthropogenic impacts are comparable in magnitude, uniqueness, and geologic perseverance to the global changes that mark previous major geologic time intervals. To identify the geologic signals that characterize the Anthropocene, we studied two sediment cores from Searsville Reservoir, located at Jasper Ridge Biological Preserve in the eastern foothills of the San Francisco Peninsula, California. These cores have distinct seasonal layers and exceptionally high sedimentation rates—they are 944.5 and 852.5 cm long, and span from 1900 to 2018 CE—which has allowed detailed investigation of the Holocene-Anthropocene transition. One of these cores is being considered as a Global Boundary Stratotype Section and Point for the Anthropocene.

We analyzed concentrations of mercury, lead, and other heavy metals in the cores and found a temporal sequence of increases and declines which likely reflect atmospheric concentrations and historic records of global mining intensity and peak commercial uses. Stable isotope analyses show depletion of ^{13}C caused by burning of fossil fuels, and depletion in ^{15}N caused by global increases in reactive nitrogen—signals which track known atmospheric patterns over the last century. We also analyzed the radionuclides Plutonium-239,240 and Cesium-137, generated by nuclear bomb testing which began in 1945, peaked in 1962, then declined sharply beginning in 1963. In Searsville, the first appearance of ^{239,240}Pu was in late 1946, and both ^{239,240}Pu and ^{137}Cs peaked in 1963, consistent with a lag of 1-2 yrs between ejection of into the atmosphere and deposition. Local indications of human impacts are evident in the pollen and plankton microfossil assemblages and are linked to well-documented historic events in the watershed. Our analyses document the local expression of both local and global human impacts at Searsville and are providing context and critical data for a proposed watershed restoration project. Searsville is particularly emblematic as a geological record of the Anthropocene because the section is itself a direct consequence of human activity—the emplacement of a dam.

Cumulative numbers of anthropogenic fingerprints as a potential marker of the onset of the Anthropocene—an example of the Beppu Bay stratigraphy

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For assessment of the potential of the Beppu Bay sediments as a Global Boundaries Stratotype Section and Point (GSSP) candidate for the Anthropocene, we have integrated datasets of 99 proxies. The datasets for the sequences date back 100 years for most proxy records and more than 1300 years for several records. The cumulative number of occurrences of the anthropogenic fingerprints reveals unprecedented increases above the base of the 1953 CE flood layer, which coincides with an initial increase in global fallout of $^{239+240}$Pu. The onset of the proliferation of anthropogenic fingerprints was followed by diverse human-associated events, including a rapid increase in percent modern ^{14}C in anchovy scales, changes in nitrogen and carbon cycling as recorded by anchovy δ^{15}N and δ^{13}C, elevated pollution of heavy metals, increased depositions of novel materials, the occurrence of hypoxia and eutrophication, unprecedented microplankton community changes, abnormally high spring air temperatures, and lithological changes. These lines of evidence indicate that the base of the 1953 CE flood layer is the best GSSP-level candidate in stratigraphy at this site. The cumulative number of anthropogenic fingerprints continues to be high level (no longer decrease) or to increase as long as human impacts on the geological environments persist. The large cumulative number of anthropogenic fingerprints characterizes the Anthropocene Series and is a potential measurable marker for detecting the onset of the Anthropocene.

The Śnieżka peatland as a candidate for the Global Boundary Stratotype Section and Point for the Anthropocene series

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The subalpine, atmospherically fed Śnieżka peatland, located in the Polish part of the Sudetes, is one of the nominated candidates for the GSSP of the Anthropocene. Data from two profiles, Sn1 (2012) and Sn0 (2020), from this site are critical for distinguishing the proposed epoch, while an additional core Sn2 is presented to support main evidence. The Sn0 archive contains a wide array of critical markers such as plutonium (Pu), radiocarbon ($F^{14}C$), fly ash particles, Hg and stable C and N isotopes which are consistent with the previously well documented $^{210}Pb/^{14}C$ dated Sn1 profile, which provides a high-resolution and comprehensive database of trace elements and rare earth elements (REE), Pb isotopes, Pu, Cs, pollen, and testate amoebae.
The 1952 worldwide appearance of Pu, owing to its global synchronicity and repeatability between the cores, is proposed here as a primary marker of the Anthropocene, supported by the prominent upturn of selected chemostratigraphic and biostratigraphic indicators as well as the appearance of technofossils and artificial radionuclides.

Distribution and accumulation of SCPs and charcoal particles in the Coosa River, AL, USA

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Charcoal particles and spheroidal carbonaceous particles (SCPs) in sediments can provide information for paleofire reconstruction, identifying anthropogenic carbon pollution, and dating sediment cores. Recently, SCPs in lakes and peatbogs have been proposed as a potential Global Boundary Stratotype Section and Point (GSSP) for the Anthropocene. Numerous studies of SCPs and charcoal in peatbog, lake, and reservoir sediments have been published. However, few studies have examined their accumulation in riverine sediments, even though fluvial accumulation and transport are plausible mechanisms for their eventual sedimentation in these systems. We address this knowledge gap by analyzing sediments (n=14) along the Coosa River in eastern Alabama (AL), USA near two electric generating plants that have burned coal since the mid-1950s. One plant was completely converted from coal to natural gas in 2015, whereas the other still utilizes some coal combustion but was partially converted to natural gas in 2016. For this study, sediments were collected upstream, adjacent to, and downstream each of the power plants. SCPs and charcoal were measured in replicates (n=30 or 50) for each site. For SCPs, the particle size distribution was also measured using CharTool. We found that for smaller subsample sizes (n<15), the SCP and charcoal counts were highly variable. For SCPs, larger subsample sizes (n>30) followed normal distributions that could adequately be described by a mean and standard deviation ($\bar{x}$=133-261 and σ=46-136). For charcoal, often, the particle count frequency did not follow a normal distribution even at high subsample sizes ($\bar{x}$=278-611 and σ=194-376). These results suggest that quantifying SCPs and charcoal based on a single subsample is insufficient to describe the particle concentrations, particularly in fluvial systems. The mean particle count and size distribution for each site were also mapped spatially to understand accumulation and transport in the context of the two power plants. This study helps to quantify the flux and spatial distribution of SCPs and charcoal in a fluvial system, which has important implications for understanding particle sources and accumulation in lake sediments. Further, our replicate counts have important implications for the use of SCPs as a GSSP for the Anthropocene.

Relationship between Anthropocene, environmental inequality and Sacrifice zones: a study case informed by contemporary paleopollution archives

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Despite the progress and economic contribution of industrialization over the last 250 years, such productive activities have altered the functioning of the Earth System but with socio-environmental costs bearing disproportionally on low-income communities. Such is the case of sacrifice zones -i.e., territories severely degraded by polluting activities- which have proliferated worldwide since the mid-20th century. By this means, sacrifice zones are deemed as Anthropocene spaces since environmental inequality persists by decisions aimed at increasing consumption/production demands. How global, national, and local socio-economic and policy cycles interact in perpetuating environmental injustice in these territories, however, have been rarely explored. Here, we evaluate the relationship between environmental injustice and Anthropocene by integrating macroeconomic trends, data for social inequality and environmental policies as well as a centennial-scale reconstruction for the pollution burden by unregulated Potentially Toxic Elements (PTEs, i.e., metal(loid)s). Specifically, we outline a case study for the Puchuncaví sacrifice zone (Chile). The trajectory for local pollution loads is informed by geochemical characterizations of dendrochronological and sediment records that span the period between 1872 and 2008 CE. Our results point to an ever-growing load of PETs paced by the staggering growth of local industrial activities, which has ultimately been spurred by national and transnational market forces. Local poverty levels declined concomitantly, but the reduction in environmental inequality is marginal as pollution burden worsened through time. Although national and international regulations succeeded in controlling short-lived pollutants through technological solutions, these instruments appear insufficient in mitigating PETs. This implies that environmental policies to address risks in sacrifice zones should not only focus on mitigation, but also on reducing exposure to hazards accumulated over decades. That is, considering rehabilitation actions based on the preventive principle. For instance, in our study case the just transition process is not guaranteed -even under a carbon neutrality scenario- as this territory will continue to be affected by long-lived PETs. Thus, integrative historical reconstructions for socio-environmental processes have the potential to inform the discussion on governance in the Anthropocene. Particularly, regarding how environmental justice could be assessed when economic models prioritize growth to the detriment of the human and environmental well-being.

Session 41: Late Quaternary desertification, landscape changes, paleoclimate, and human adaptation

Late Quaternary palaeoenvironment history of the Kashmir Valley, Western Himalayas

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The climate during the Late Quaternary Period was characterized by the repetition of cold glacial and warm interglacial periods, with glacial periods being much longer than interglacial periods. The Karewa group of sediments in the Kashmir Valley is an excellent archive to study the climate fluctuation of the Late Quaternary Period. We studied loess-palaeosol sections and lake sediment sequences of the Kashmir Valley to understand the evolution of the Late Quaternary palaeoclimate. Statistical deviation in the multi-proxy data of the loess-palaeosol sections reflected variable depositional and post-depositional processes that operated in the study area. The palaeosols of the studied profile indicated polycyclic nature probably developed during the cycles of climate amelioration. The presence of well-developed AhBtk palaeosol during the MIS-3 indicated a wetter climate during this phase. A steady increase in the $CaCO_3$ content and the C/N ratio in the loess indicated arid and drier climatic conditions during the MIS-2. Multi-proxy studies (δ13C, δ15N, major oxides and trace geochemistry, etc.) carried out on various lacustrine trenches and cores revealed the occurrence of a cold climate from 29 to 20 ka, with peak intensity at around 26 to 24 ka. The Kashmir Valley observed substantial glacial advance during the Last Glacial Maximum. The proxy records revealed continuous climate warming from 20 to 12 ka. The lacustrine records of the Holocene Epoch revealed signatures of cold climate phases that corresponded to the Bond events 0, 3, 4, 5, and 7. This indicates the substantial influence of the westerly-dominated climate during the Holocene Epoch. The sedimentary process revealed strong anthropogenic influence due to forest land clearing and agriculture extension during the last 2 ka.

Tropical Rainforest Paleoenvironmental Shifts Since The Late Pleistocene Based On Lake Sediments, Kodaikanal-Nilgiris, India

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Limnological studies in Kodaikanal (Kukkal ~1890 masl, Berijam Lakes ~ 2165 masl, and Parsons lake~2285 masl) were carried out to determine paleoenvironmental shifts and their possible impact on vegetation since the late Pleistocene period. This region dominantly receives the southwest monsoon rains from June to September. Lake trenches and sediment cores retrieved from these lakes were radiocarbon dated and the ages reveal non-linear phases of deposition. Berijam lake core is dated from 2400 yrs BP to the present and older ages for Kukkal (9000 yrs BP to Present) and Parsons Lake (~29,800 yrs BP to present). Integration of all the proxy data signifies six distinct paleoenvironmental phases: 1) Warm and humid conditions with a high lake stand before the last glacial maximum (LGM- ~29,800 cal yr BP), subsequently altering to a relatively cool and dry phase during the LGM. 2) Drier conditions and lower precipitation occurred between ~16,300 and 9500 cal yr BP causing vegetation to shrink and possibly being confined to moister pockets or riparian forest cover. 3) An outbreak in the shift of monsoonal precipitation was witnessed at the beginning of the mid-Holocene in the Parson's lake, around 8400 cal yr BP, implying alteration in the shift toward warm and humid conditions, resulting in relatively high pollen abundance for evergreen taxa. However, wet, Holocene climatic optimum (9000 yrs to 5000 yrs BP) was noted in the Kukkal sediment core. 4). From 5000 yrs BP to the present, drier conditions prevailed due to the decline in southwest monsoon intensity and its amount. During this long dry period, several wetter events of shorter duration occurred. 5). Medieval warm period and Little Ice Age events were noted in the Berijam lake core. 6) Around ~1850 cal yr BP, a shift to heavier $\delta^{13}C$ values with the emergence of moist deciduous plants points to drier conditions. Anthropogenic activity contributed to the high percentage of *Acacia* and *Pinus* pollen during the Little Ice Age. Variations in the grain size distribution indicate paleoflood events influenced by regional climatic conditions and identified by the silty sediment matrix around □29,838 and □8405 cal yr BP.

Late Quaternary sediment characterization, neotectonics and climatic record of Ladakh, Northwest Trans-Himalaya, India

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Ladakh is a cold arid high altitude desert lying in the Trans-Himalaya is surely a treat for geographers and geologists eyes because of its lunar/martian landscapes; exposures of sedimentary, metamorphic, and igneous rock types; glacial, fluvial-lacustrine sediments and active tectonic and climatic processes. This work sums up the sedimentary characteristics, tectonic and climatic history with examples from the variety of sediment exposures along the Indus River and Ladakh Range. The overall geomorphological evolution of Ladakh is basically governed by two sets of geological processes- the continental scale geological processes that have primarily provided the basic framework for the landscape and second the regional/local scale geological processes in which the role of tectonics and climate which has been significant in determining the glacial, fluvial, lacustrine and aeolian processes. The transient topography of the region is attributed to -movement along active Stok thrust along the Indus Sut ure Zone; long-term steady-state perturbed by climate change; situated in the orographic rain shadow zone, and landscape not in the cosmogenic steady state due to topographic effect and methodological uncertainties of data. A number of lake sediments (paleo and proglacial) were studied with a multi-proxy approach for recording the climate. A composite and complete picture of the Holocene climatic variation shows five prominent arid phases mark the Holocene period in Ladakh (~10800-10000; ~8800-8600; a longer arid phase at ~5200-2600 with increasing aridity towards the top part; ~1700-1500 and ~500 cal yr BP) intervened by comparatively warmer conditions in between. Two sources of precipitation (Westerlies and ISM) are responsible for governing the hydro-climate of the region. The westerly dominates at the beginning of the Holocene while the mid-Holocene sees the advent of ISM to the region. The lake records and other published records from the region show that this change in the moisture source has occurred several times in the Holocene- 7200, 5200, and 2600 cal yr BP although the westerly has been a dominant precipitation source in the Ladakh region through most of Holocene. Both exogenic and endogenic forcings are responsible to shape the topography of the region.

Holocene climatic variations inferred from the multi-proxy record from Chilika Lagoon, East coast India

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Holocene climatic variability and associated societal growth and demise have received considerable attention and key research domain because of the concerns about their reoccurrences in the future. Therefore, several important studies have been conducted focused on understanding the Holocene aridification at ~8.2 and ~4.2 ka BP around the globe. The present study focused on the Holocene palaeoclimatic records reconstructed based on new multi-proxy high-resolution geochemical and ^{14}C chronological data from the Chilika Lagoon (Odisha), east coast of India. Around 1.3 m long sediment core, obtained from the lagoon's southern shore, showed a consistent sedimentation history between 8.49 and 0.99 ka BP. The variations in total organic carbon (TOC) content, major and trace element abundances, and the isotopic signatures of organic carbon composition ($\delta^{13}C$) pointed out a significant climatic effect from the dry events that occurred at 8.2 and 4.2 ka BP. Additionally, a significant warm climate anomaly was also noted at 1.2 ka BP. It's interesting that increased sedimentation rates were observed after 4.2 ka, which is linked to a substantial shift in the settlement pattern and human activity. As a result, we postulated that the eastern part of Odisha witnessed human migration and change in agricultural practices in line with societal changes documented in north-western India after the 4.2 ka aridification event. We speculated that people moved to new locations, which eventually led to increased pastoral activity in the newly occupied regions. Consequently, the region experiences increased land use and land cover changes, as well as increased soil erosion, which corresponds to high sedimentation rates. The fact that several periods coincide with significant societal upheavals shows the importance of Holocene climate variability for humans.

Palaeohydrological reconstruction of Laguna de Villena (SE Iberian Peninsula) since 9100 yr cal BP to 5400 yr cal BP inferred from high-resolution geochemical analyses

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Endorheic saline lakes are usually highly sensitive to hydrological processes. Therefore, the sensitivity of this environments means that, with multi-proxy analysis, they are good sedimentary systems to investigate the impacts of past climate changes. This work presents the results of the geochemical analysis of a core from Laguna de Villena, ephemeral salt-lake located in southeastern Spain. Powder X-ray diffraction (PXRD) measurements have been performed on 84 samples, from 120 cm to 284 cm depth. The selection of the samples corresponds to the geochronology we focus on in this study, from cal. 9100 yr. BP to 5500 yr. BP, during the Early-Middle Holocene transition.

Numerous mineral phases were identified from the PXRD and include calcite, magnesium calcite, muscovite, aragonite, quartz, dolomite (including Fe-rich dolomite), gypsum and halite. These phases are classified into four groups: 1) calcite, Mg-calcite and muscovite, linked with increased freshwater either via torrential rainfall or discharge from runoff water; 2) quartz, associated to increased terrigenous input; 3) halite and aragonite, which indicate more arid conditions and a decrease in the water level; and 4) gypsum and dolomite, which indicate increased in salinity and is linked to arid conditions. However, because ambiguous gypsum's origin, water table reconstruction have been performed with aragonite, calcite and dolomite.

The results show a significance water table variability during the Early-Mid Holocene. Humid conditions and an increase in the water table will be from cal. 7100 yr. BP to 6800 yr. BP, and from cal. 5900 yr. BP to 5500 yr. BP. During these two periods, weight contents of calcite, magnesium calcite and muscovite are higher and, on the opposite, aragonite and dolomite show low values. On the other hand, arid conditions and a decrease in the water level will be from cal. 9100 yr. BP to 8900 yr. BP, and peaks in cal. 8300 yr. BP, 7800 yr. BP, 6600 yr. BP and 6000 yr. BP, when there are positive trends of aragonite and dolomite, and negative trends of calcite, muscovite. As a conclusion, climate variability is reflected in geochemical properties as well as water level fluctuations are linked to climate fluctuations.

Luminescence chronology of Diêm and Mang Chieng Caves in northern Vietnam, and the archaeological and palaeoenvironmental implications

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Northern Vietnam is a critical migration corridor for late Pleistocene hominins in East Asia. The abundant cave sites discovered in this humid tropical region are important for understanding the complex human history of Southeast Asia, as well as their linkages to prehistoric cultures in southern China. Reliable chronologies are essential for unravelling the archaeological significance of these sites. In this paper, we present chronological results of single-grain (SG) optically stimulated luminescence (OSL) dating of two karst caves located in Cúc Phương National Park in northern Vietnam—Diêm and Mang Chieng Caves. Both sites contain multiple shell-rich layers associated with prehistoric human occupation, as well as stone artefacts exhibiting features typical of the 'Hoabinhian' culture. SG equivalent dose (De) distributions of quartz grains and micromorphological features indicate that most of the shell-rich layers have been subjected to post-depositional mixing. The De populations representing the original depositional ages of the layers were identified according to the SG De distribution pattern and the consistency between the ages and depths of the samples, and the impact of shell fragments on the estimation of the environmental dose rates—and, hence, the OSL ages—is modelled and discussed. A chronological framework of the cave sediments is established based on Bayesian age-depth modelling. The chronologies for the two cave sites reveal the emergence of the Hoabinhian in northern Vietnam earlier than 20,000 years ago, suggesting this region has one of the earliest records of this culture in Southeast Asia. The environmental context of hominin occupation of the two caves is discussed by combining these chronologies with microstratigraphic study of the cave deposits and with other evidence of palaeoclimatic changes in mainland Southeast Asia.

Early- to mid-Holocene lake formation in NW Arabia was driven by the West African Monsoon

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The early- to mid-Holocene humid period (HHP) is well established for North Africa and the southern Arabian Peninsula. Evidence from northern Arabia has been ambiguous so far. The impact of a more humid climate on hydrography and the vegetation has been controversially discussed, with some researchers challenging the existence of perennial lakes in northern Arabia at that time. Here, we present a new Holocene shoreline record mainly consisting of bioclastic deposits (gastropods, barnacles, foraminifers, ostracods) up to several metres thick. These deposits are partly eroded and frame an endorheic basin in the oasis of Tayma (NW Arabia) indicating the presence of a >17 m deep and >22 km² palaeo-lake. Taphonomic macrofossil analysis based on a newly developed key of preservation reflects the rising lake (base of the profile) and the highest lake stand (mid- to upper part of the deposit) with many entirely preserved autochthonous barnacle carapaces. Sub-decadally resolved proxy data from the varved lake sediments at the centre of the basin (micro-facies analyses, pollen record of shoreline and submerged vegetation, TOC, stable isotopes) and varve and radiocarbon dating point to five phases of lake development between 8,800 and 7,900 cal yr BP. The most humid phase with highest lake levels corresponding to the mapped shoreline deposits is dated to 8,550–7,950 cal yr BP. A transient simulation conducted in the Earth System Model MPI-ESM for the last 8000 years indicates much stronger late-summer rainfall than today during early to mid-Holocene embedded in the intensified West African monsoon (WAM) circulation. Based on the model, the monsoon rainbelt reached substantially further east and north onto the Arabian Peninsula 8000 years ago and retreated back to its modern position during the mid- to late Holocene. Tayma is located at the distal fringe of this increased monsoonal influence. This may explain the very short existence of the perennial lake of a few centuries only, compared to the HHP's millennial-scale impact on landscapes in areas closer to the core domains of the WAM and also the South Asian Monsoon.

Session 42: Ecosystem change and hunter-gatherer behavioral decisions in the terminal Pleistocene Pacific Rim

The American Upper Paleolithic and the Coastal Migration Theory

Dr. David Madsen [1], ***Dr. Loren Davis*** [2]

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In North America there are now enough sites with relatively large stone tool assemblages predating ~14.5 ka, well before an ice-free corridor became available, to allow some assessment of the underlying characteristics of the lithic tradition they share and to hypothesize where and when in the world this lithic tradition may have originated. These sites share a broad technological similarity involving the use of dual core-and-blade and biface technologies similar to that found in the late Upper Paleolithic of northeast Asia. In the core and blade system, flat-faced, wedge-shaped, and occasionally conical cores are used to produce elongate blades and/or blade flakes which constitute one of the primary tool forms used by the initial occupants of North America. These elongate, prismatic blade flakes were often used unmodified as cutting tools but were also retouched into a variety of other tools such as scrapers, drills, and projectile points. In the parallel biface technology comedial flaking was used to produce proportionally flaked bifaces, with many of the removal flakes used expediently as modified flakes. These dual technological approaches were often merged to produce small projectile points, usually less than 5 cm in length, which vary in morphological form from site to site but often include stemmed point forms. Similar dual core-and-blade and biface technologies are found in Late Upper Paleolithic assemblages in northern Japan dating to ~20 ka. We suggest a group with a similar lithic technology became isolated somewhere in the vicinity of the Japan/Paleo-Hokkaido, Sahkalin, Kuril (PSHK) region of northeast Asia, developing genetically into ancestral ancient Native American population. Between ~22-18 ka a subset of this population began migrating by foot and boat along the southern Beringian coast and down the Alaskan and Canadian coastline into the Americas. By ~15-16 ka they had become widely dispersed across North America south of the continental ice sheets.

Geochronology and techno-typology of the stemmed point on blade in the Japanese archipelago

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The stemmed point across the northern Pacific Rim, which includes the Japanese archipelago, has recently been the focus of discussion with respect to the peopling of Northeast Asia and the Americas. This presentation discusses the geochronology and techno-typology of the stemmed point in the Japanese archipelago. During the late Pleistocene, several mid-latitudinal islands of this archipelago formed a large landmass named Palaeo–Honshu (P–Honshu). The stemmed point abruptly appeared in the Kyushu region, the western edge of P–Honshu, for a short period between 29,300 and 27,500 cal BP and was utilized as a primary hunting weapon. It was first named the *hakuhen-sentoki* stemmed point (HSP), which is produced by notching both laterals of the proximal end of a pointed blade. The techno-typology of HSP has a distinct similarity with the stemmed or tanged point of the adjacent Korean Peninsula, which long prospered from between about 40,000 to 20,000 cal BP, strongly suggesting that the HSP was derived from the tanged point in the peninsula and was adopted by foragers in the Kyushu region at the beginning of MIS2. After 27,500 cal BP, HSP rapidly changed their form into flake-based ones and subsequently disappeared. This observation indicates a short-term/small-scale human migration/interaction between the Korean Peninsula and Kyushu led to the emergence of the HSP in Kyushu. Outside Kyushu, several archaeological sites bearing the HSP were scattered throughout P–Honshu. However, among the whole hunting weapons at each site, its percentage is quite low, indicating that the HSP outside Kyushu appeared occasionally or was simply an alternative to different hunting weapons. Geochronologically, the traditional connection between the HSP and the bifacial stemmed point of the Incipient Jomon, after 16,000 cal BP, has not been clarified on P–Honshu.

Using geophysical and geological data to reconstruct submerged coastal landscapes along the eastern Pacific margin of North America

Prof. Jillian Maloney [1], ***Dr. Amy Gusick*** [2], ***Prof. Shannon Klotsko*** [3], ***Dr. Todd Braje*** [1], ***Dr. Loren Davis*** [4], ***Dr. Jon Erlandson*** [5], ***Mr. David Ball*** [6]

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During the last glacial maximum, eustatic sea level was ~120 m below present, exposing most of the world's continental shelves, and providing a vast landscape for human migration and occupation that is now submerged due to post glacial sea-level rise. Reconstructing the late Pleistocene landscape of the continental shelf is critical for locating submerged archaeological sites and improving our understanding of human migration pathways and human adaptation to a changing climate. We present high-resolution subbottom and sediment core data from two locations along the eastern Pacific margin of North America: the Northern Channel Islands, California, and central Oregon. These data were used to identify paleoshorelines, paleochannels, and intact terrestrial and estuarine deposits preserved beneath Holocene marine sediment. The identification and mapping of these paleolandforms is used to characterize how continental shelf landscapes have evolved since the last glacial maximum and assess the relevant forcing mechanisms of coastal and nearshore landscape change. These data are critical for landscape reconstruction models and refining the search for submerged archaeological sites.

Submerged Pleistocene-aged Landscapes and a Coastal Route of Entry into the Americas

Dr. Amy Gusick [1]***, Prof. Jillian Maloney*** [2]***, Dr. Todd Braje*** [2]***, Prof. Shannon Klotsko*** [3]***, Dr. Jon Erlandson*** [4]***, Mr. David Ball*** [5]

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Sea-level rise following the Last Glacial Maximum submerged millions of square kilometers of coastal landscapes around the world, complicating efforts to understand the paleolandscapes, paleoecology, human dispersals, and the cultural history of these now drowned regions. This situation is particularly troublesome in the Southern California Bight on the eastern Pacific Coast where sea-level rise inundated thousands of square kilometers of coastal terrain, including entire islands. Still, this region boasts one of the highest densities of terminal Pleistocene and early Holocene archaeological sites in the Americas, making it an ideal location to consider early maritime human populations and a hypothesized Pleistocene coastal route of entry into the Americas. Over the past few decades, researchers have identified hundreds of subaerial Paleocoastal archaeological sites in this region, but these likely represent a fraction of the resources and maritime spaces used by peoples present across the terminal Pleistocene and earliest Holocene landscape. Recognizing that these resources and spaces are critical to understanding our human past, recent interdisciplinary research is focusing on the area's submerged paleolandscapes to identify how rapidly shifting habitats and evolving landscapes affected human migration, settlement, and resource strategies during periods of drastic climatic change. This marine social science research is informed and supported by geological, biological, and geophysical marine science disciplines and considers both the landscape and seascape as a continuous ancient maritime cultural space. This presentation will focus on this interdisciplinary research that investigates the timing and nature of environmental and ecosystem change to inform the search for sensitive cultural maritime landscapes. Data gleaned from these landscapes provide critical data to understand the history of maritime adaptations and a Pleistocene coastal route of entry into the Americas.

Western Pacific landscape changes during the Late Pleistocene and the early Holocene related to global ice volume changes

Prof. Yusuke Yokoyama [1]

1. *Atmosphere and Ocean Research Institute, University of Tokyod*

Variations in global mean sea level (GMSL) are controlled mainly by growth and decay of continental glaciers and temperatures that are closely correlated with the mean global climate state such as glacial and interglacial cycles. Fluctuations on millennial time-scales produce locally complex changes coastlines, associated with short-term influence on species development including modern human. Recent developments in sampling and analytical methods enable us to more precisely reconstruct past sea-level changes using geological indicators dated by radiometric methods. These revealed rapid changes in sea levels during the late Pleistocene and Holocene from the time into and out of the last glacial maximum (LGM: 20ka). The GMSL was around -125 to -130m during the LGM, approximately 10 kyrs long, was the coldest period in Earth's recent climate history and tropical sea surface temperatures were about 3 to 5 degrees Celsius lower. The LGM began when GMSL abruptly dropped by about 40 m around 31 ka and was followed by about 10 kyrs of rapid deglaciation into the Holocene. Ups and downs of GMSL reached as fast as more than 3 milli metres per year. This leads the coastline changes and the opening or closure of ocean passages, as narrow bridges allowing limited species crossing or as fully colonized corridors, had severe impact on eco-fragmentation and the expansion or contraction of species. This presentation will review the sea-level and climate during the last late Pleistocene to the early Holocene in Western and North Western Pacific region.

Contents of the talk is related to following references: Yokoyama et al., 2022 (Nature Communications, 13, 6261), Yokoyama and Purcell, 2021 (Geoscience Letters, 8, 13), Yokoyama et al., 2018 (Nature, 559, 603), Yokoyama and Esat, 2011 (Oceanography, 24, 54-69), Hunebuth et al., 2011 (Earth Science Reviews, 104, 92-110)

Microblade and bifacial point technology for Late and Terminal Upper Paleolithic in Hokkaido, northern Japan

Dr. Daigo Natsuki [1]

1. The University of Tokyo

Recent studies on peopling of the America have focused on stemmed points in the late Pleistocene as evidence for coastal migration through the Pacific Rim. This study examines the diversity, age and distribution of Late Upper Paleolithic (LUP) and Terminal Upper Paleolithic (TUP) lithic assemblages in Hokkaido, with a particular focus on microblade and bifacial point technology. During the late Pleistocene, Hokkaido was a southern margin of the "Paleo-Sakhalin/Hokkaido/Kurile Peninsula", connected to mainland of northeastern Asia. LUP and TUP lithic assemblages have been found from strata above En-a tephra (21,000-19,000 cal BP) in Hokkaido. The LUP and TUP assemblages are characterized by a variety of microblade technology, blade tools, and bifacial tools, and can be divided into at least eight technocomplexes. Although a large number of excavations and studies of archaeological sites in Hokkaido have reported many results radiocarbon dating associated with the UP, there were few dates acceptable for the chronological order of LUP and TUP due to the thin sediment deposition on the gentle slopes and post-depositional processes. Acceptable dates associated with the assemblages are 18,000-17,000 cal BP for the technocomplex of the late LUP, which includes the Togeshita type and the Sakkotsu-type microblade cores. Many previous studies have emphasized bifacial stemmed points, stone axes, and large blades as archaeological components of the TUP in order to compare the TUP (or the Late microblade assemblages) in Hokkaido with the Incipient Jomon period after 16,000 BP in the Paleo-Honshu. Analysis of the lithic assemblages and their associated ages in this study reveals that several technocomplexes previously included in the TUP are incorporated into the early LUP (21,000-18,000 cal BP). The result makes it possible to better understand temporal changes in lithic technology that are consistent between the Paleo-SHK and the Paleo-Honshu during the terminal Pleistocene. This implies that the migration of people and the diffusion of lithic tool technology, including microblade and bifacial point technology, between the Paleo-SHK and the Paleo-Honshu rapidly triggered widespread changes in adaptive strategies in response to environmental changes.

Palaeoenvironment of southeast Alaska during the terminal Pleistocene

Dr. Kelly Monteleone [1], ***Dr. Rosita Worl*** [2], ***Dr. Andrew Wickert*** [3], ***Dr. Richard Barnes*** [4], ***Dr. Kerry Lee Callaghan*** [5]

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At approximately 17,000 cal BP, sea levels in southeast Alaska dropped by as much as 165 m below modern. The continental shelf would have been along the coastal migration route of early people to the Americas. The biological evidence indicates glacial refugia and the terrestrial archaeological record indicates that people were present by at least 12,000 cal BP. The main focus is on Shakan Bay, a sheltered inlet in northwest Prince of Wales Island, southeast Alaska. Shuká Káa Cave just north of Shakan Bay dates to 12,129 cal BP and includes lithics from south of Shakan Bay, indicating that people knew this area before 12,000 cal BP. Additionally, a submerged fishing structure or weir has been identified at approximately 50 m or 11,100 years ago based on the current sea level reconstruction. This project combines environmental reconstruction, an archaeological resource-based predictive model, and marine geophysical surveys to better the changing environment at the end of the Pleistocene and early Holocene and human responses to these changes.

The peopling of Eurasia and the Americas inferred from human genome analysis

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Eastern Eurasia at the end of the Late Pleistocene was the gateway to the northern part of the Americas. Modern and ancient human genome analyses can provide insight into the migration process and reveal the paths taken by populations that arrived in the Americas. The people had to reach first the Northeastern part of Asia, but the route they followed to cross the vast distances in the Asian continent is still a matter of debate. Two major routes have been proposed: The first one is a route that circumvents the Himalayas going through the North, and the second one is a route that occurred through the Indian subcontinent that is the South of the Himalayas. Due to the cooler climate on the northern route, preservation of biological remains is better than on the southern route. Moreover, the southern route has a warmer and more humid environment. This makes it an unsuitable place for the preservation of old bones. For these reasons, ancient DNA research in the southern region was more difficult and fell behind that in the northern region. However, research on there has been accumulating in recent years due to improved sequencing techniques and the discovery of human remains containing adequate amounts of endogenous DNAs. The findings reinforce our understanding of when and how Upper Paleolithic Northeast Asian peoples inhabited the northern part of the Pacific rim. Therefore, we summarize the findings of migration and admixture inferred from genome analyses, and consider the first migrants to the Americas. In addition, the possibility of detecting traces of occupation based on paleoenvironmental analysis using sedimental ancient DNA analysis is also presented.

Using Archaeological and Human Genetic Evidence to Evaluate the Migration Routes taken by the Earliest Americans into Unglaciated North America at the end of the Pleistocene

Dr. Michael Waters [1]

1. *Center for the Study of the First Americans, Texas A&M University*

The Laurentide and Cordilleran ice sheets of North America reached their maximum extent during the Last Glacial Maximum (~26,000-19,000 yr B.P.) and blocked the movement of people into unglaciated areas to the south. Eventually, as temperatures increased, the western edge of the Cordilleran ice sheet receded opening a Pacific coastal corridor and the western edge of the Laurentide ice sheet retreated opening an inland corridor. Geological and geochronological evidence indicates that the inland corridor opened by ~13,800 ± 500 yr B.P. and the coastal corridor was passable by ~16,000 yr B.P. Because the oldest archaeological evidence from either corridor only dates to the Younger Dryas, the route taken by the first people to enter the Americas remains unclear. However, genetic studies indicate that people were south of the continental ice sheets by ~15,700 yr B.P. Additionally, archaeological evidence from the Debra L. Friedkin and Gault sites, Texas; Hebior and Schaefer sites, Wisconsin; Page-Ladson site, Florida; Paisley Caves, Oregon; Cooper's Ferry site, Idaho; and the Manis site, Washington, indicate that people entered the Americas by ~16,000 yr B.P. and were widespread in North America by ~15,000-14,500 yr B.P. Based on the current geological and geochronological evidence from the coastal and inland corridors, the genetic and archaeological evidence from what was unglaciated North America is most consistent with the first Indigenous people entering the Americas via a coastal route.

Subsistence strategies of prehistoric hunter-gatherers on a small island of Tokunoshima, Japan

Prof. Katsuhiro Sano [1], ***Prof. Yoshihisa Suyama*** [1], ***Prof. Yasufumi Iryu*** [1]

1. *Tohoku University*

Tokunoshima is a small island located in the middle of the Ryukyu Islands, around 400 km to the south-southwest from Kyushu (the third-largest island of Japan), and around 800 km to the east-northeast from Taiwan. Recent archaeological investigations indicate that hunter-gatherers have continuously occupied on the Tokunoshima island since the Terminal Pleistocene at ~14 ka. However, cxcept for the Ryukyu Islands, few small islands in the world have been successfully colonized by prehistoric hunter-gatherers, as their subsistence required large landmass. It is little known how Ryukyu hunter-gatherers successfully adapted to the environment on small islands where natural resources were limited. In this talk, we present preliminary results of the FRiD (Frontier Research in Duo) grant project that tries to better understand subsistence strategies of the island hunter-gatherers that enabled them to settle on a small island over 10,000 years. Besides studies on archaeological materials, including stone artifacts, pottery, and ornaments, we analyzed carbon and oxygen isotope records in *Tridacna*shells recovered from prehistoric sites on the Tokunoshima island to precisely reconstruct the paleoclimate. We also undertook ancient and present DNA analyses of plant and animal samples to detect the roots of the domestication. The multidisciplinary approaches provide us with an opportunity for elucidating adaption strategies of the hunter-gatherers to the drastic climate changes from the Terminal Pleistocene to the Holocene on the small island of Tokunoshima.

Pottery, lithics, and geochronology: late Pleistocene ceramic users of the northwestern Pacific rim and human migration event to the Americas, an updated view

Dr. Fumie Iizuka [1], ***Prof. Masami Izuho*** [2], ***Dr. Loren Davis*** [3], ***Dr. David Madsen*** [4]

1. University of Missouri, 2. Tokyo Metropolitan University, 3. Oregon State University, 4. University of Nevada-Reno

Current evidence from archaeological sites in North America suggest that humans were present south of the continental ice sheets by ca. 16,000 cal BP. Archaeological data, paleoenvironmental conditions, and genomic data combined indicate that Native American ancestors likely migrated from Northeast Asia along the coast of Pacific rim. On the western Pacific rim, the Japanese archipelago has ceramic-bearing sites confidently dated to the late Pleistocene. These occupations are loosely categorized as the Incipient Jomon. Due to general geochronological overlaps, scholars have compared Jomon-related lithic technology, and genetic signatures with Pleistocene North American context. Results have been somewhat controversial. While there is no genomic data that suggest a direct connection of Jomon and Native American ancestors, bifacial stemmed points in the Incipient Jomon have been inferred as having similarities to assemblages found along the eastern Pacific rim. Unlike the Incipient Jomon sites, however, pottery is absent at first American sites. In this presentation, we critically review data on Incipient Jomon ceramics and associated lithics and geochronology. This study updates the work by Iizuka (2018) by paying more attention to the timing of the emergence of lithic types that overlap with early American assemblages. Our research suggests that in the Paleo-Sakhalin-Hokkaido-Kuril Peninsula, pottery and lithic technology of the Incipient Jomon did not emerge before ca. 14,700 cal BP. Aceramic sites bearing bifacial stemmed points suggested as Incipient Jomon (Natsuki 2022) await confirmation of absolute dates; absence of pottery in this context can be due to diagenesis. In central paleo-Honshu Island, pottery appears with bifacial stemmed points, but only by ca. 15,500 cal BP. Based on currently available data, we suggest that low visibility is not the reason pottery is absent in the terminal Pleistocene Americas; pottery using behaviors associated with bifacial stemmed points with subsequent patterns in morphological changes in the western Pacific rim, emerged after humans had migrated to North America.

Hooks of the Ancient Mariners: The Oldest Specialized Maritime Technology in the Americas

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Isla Cedros, Baja California, México is a remarkable place; it is a high, mountainous and tectonically active island located on the extreme west coast of the North American continent. It is home to some of the oldest evidence for human occupation of the coast along the Pacific margin of the American continents, represented by assemblages from multiple sites demonstrating a robust maritime focus of resource harvesting with sustained occupation at prime locales. Significantly, archaeological excavation at several of these sites has also produced unequivocal evidence of specialized maritime *technology* dating to the Terminal Pleistocene in the form of the oldest fishhooks between the Bering Strait and the Atlantic. These assemblages of fishhooks were recovered from contexts securely dated by extensive radiocarbon assays to between 10,000 and 13,000 CalBP. One of the most essential evaluations of human engagement with the environment is the degree to which the natural and ecological conditions have shaped the nature and form of the human technological system. The size of this assemblage (n=42) allows some degree of investigation of concepts of design and engineering even from such a remote timeframe. These hooks are manufactured from abalone (*Haliotis* sp.) and mussel (*Mytilus californianus*) shell and range in size between less than 3cm in length to over 8cm in length. Comparing the assemblages of maritime technology from Isla Cedros, México to other early maritime systems of the Pacific Rim and elsewhere should provide a baseline for understanding the early adaptive contexts of Pleistocene migrants along the Pacific Coast of the Americas. Notably, the investigations at Isla Cedros have produced one of the largest assemblages of Pleistocene-aged fishhooks anywhere in the world.

The Search for Late Pleistocene-Aged Submerged Sites on Oregon's Continental Shelf: Methods and Recent Discoveries

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Geographic information systems-based modeling of submerged paleolandscapes along the central coast of Oregon, USA combined with offshore geophysical and marine coring studies led to the discovery of multiple submerged and buried alluvial drainage systems dating to the late Pleistocene period. Here, we briefly review the modeling, offshore surveys and coring, and subsequent analyses that led to such discoveries. These discoveries highlight the preservation of landscape-scale stratigraphic units that may hold archaeological evidence of early coastal peoples or signal the nearby presence of geoarchaeologically relevant landform targets. The archaeological implications of this research are important and far-reaching: late Pleistocene-aged landforms that were undoubtedly attractive to early coastal people are preserved on Oregon's continental shelf. Further exploration that focuses on these localities provides a viable path forward for finding archaeological evidence of early human presence on the Pacific coast of North America.

Paleoceanographic insights on viable time periods for human migration along the Pacific coastal route during the late Pleistocene

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Genomic evidence suggests that the primary founding human populations of the Americas arose from Beringia during the Last Glacial Maximum (LGM), but the timing, pathways, and modes of their subsequent southward transit remain unknown. We utilize model simulations and multi-proxy paleoceanographic data to shed light on the ocean and climate conditions in the Northeast Pacific from the late Pleistocene to early Holocene to assess viable time periods in which humans could have traversed the Cordilleran coastal corridor. Our synthesis provides new insights and constraints on the debates about the first human migrations along the Pacific Northwest coastal route. We find that the cyclonic currents along the Alaskan margin would have been strengthened during the LGM and times of enhanced meltwater input, making a southward transit by boat more difficult. We infer that the Cordilleran ice-surge episodes (“Siku events”) would have been particularly challenging for a coastal transit due to regional cooling, abundant icebergs, and strong coastal currents, possibly creating episodic (1-2 kyr) barriers to southward transit. Given the prevalence of seasonal sea ice throughout the LGM and early deglacial period, we suggest that stable winter sea ice may have acted as a platform that facilitated early coastal migrations into the Americas. Viable time periods for this scenario would likely have occurred intermittently between the Siku events when intermediate sea-ice conditions prevailed and ice-free coastal refugia were available along the Alaskan margin. We identify 24.5-22 ka and 16.4-14.8 ka as the most likely time periods to accommodate early coastal migration along the Alaskan coast.

Peri-Beringia as a cradle of the first Americans

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Recent genetic studies clearly show that eastern Eurasia was the homeland of the first Americans. The debate on the place of population standstill just before entering the Americas during or after the Last Glacial Maximum are still open. The cultural evidence, however, linking Siberian Upper Paleolithic (UP) assemblages to the Late Pleistocene assemblages south of the ice sheets in North America is yet unclear. Rather, stronger similarities of lithic technology and the assemblage pattern in the earliest assemblages of North America dated to ~16-14ka Cal BP are found in the coastal area of Asia. Those are, for example, late Upper Paleolithic assemblages found in the Paleo-Sakhalin-Hokkaido-Kurile (PSHK) Peninsula in Peri-Beringia. Here I deal with several archaeological evidence as the proxy, such as the number of sites, technological adaptation patterns, and the intensity of cultural occupations, from the late Upper Paleolithic to Incipient Jomon, between PSHK and Paleo-Honshu (P-Honshu) in order better elucidate when and how the population dispersal, continuity, admixture, and replacement occurred. Two main conclusions are obtained; (1) the biggest local climatic deterioration of Kenbuchi stadial pushed the foragers to somewhere north around 18-15ka Cal BP from PSHK, (2) complete replacement from the late UP to Incipient Jomon likely happened on PSHK, possibly after 14 ka Cal BP. The suite of blade-based, bifacial-based, flake-based lithic reduction, found in the late UP of PSHK in Peri-Beringia, which was well-adapted in coastal and forest-steppe environments, was likely advantageous for the dispersal to the south of the continental ice-sheets of north America.

Session 43: Millennial paleo-landscape reconstructions of coastal areas. From field data to modelling approaches

Geomorphology vs archaeology; the Colombaio stack and the reconstruction of Late Holocene coastal evolution at Ustica Island (Palermo, Italy)

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Both geomorphology and archaeology contribute to studies about the evolution of the coastal landscape. Landforms and archaeological remains provide valuable data for interpreting past geographies. The Colombaio stack lays at about ~60 m off the northern coast of the volcanic island of Ustica (Palermo, Italy). It is roughly parallelepiped in shape, with a basement area of ~180 m^2, a height of 17 m asl and a maximum depth of 8 m toward the sea. The total volume of the stack is about 2000 m^3. The northern coasts of the island are dominated by 20 m high volcanic sea cliffs which are affected by storm wave processes and consequent coastal retreat which can leave morphological relics, such as the stacks. Moreover, the Colombaio stack is located in front of a Middle Bronze Age coastal settlements. Finding of coeval huts and pottery at the flattened top of the stack seems to confirm its use also during historical age.

Multidisciplinary surveys, such as UAV-DP, ISR-DP and iPhone Lidar acquisition allowed us to study morphometric parameters and discuss its origin and evolution.

The stack is composed by two lava units interlaced in the form of columnar lavas and breccias. The enlargement of a joint between these units favored the formation of a sea cave inside the stack of roughly 750 m^3. Cliff retreat is also highlighted by a nearby rock, separated from inland by a dike. It can be considered as a stack-in-formation similar to the Colombaio one. The maximum depth between the coast and the stack is max 2.5 m. Consequently, during the Middle Bronze Age, people could walk to the stack, because the sea level was 2.5 m lower than nowadays. Probably it was not yet a stack, as it was not yet detached from mainland, but it was neither part of the terrace on which the archaeological settlement lays.

Multidisciplinary approach to characterize the environmental and coastal evolution at Ksar Seghir, Morocco: natural processes, extreme events and historical occupation

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In this work we present the results of the multidisciplinary study performed in river Laksar, north Morocco, aimed at characterizing the environmental evolution of the coastal area, considering natural processes, the anthropic occupation and extreme events (floods/tsunamis).
Our findings are based on a 5.4 m long sediment core - KS1 - and in high-resolution multiproxy analyses (X-Ray, magnetic susceptibility, sedimentology, organic chemistry and micropaleontology) together with ^{14}C dating to establish a chronological model.
The sedimentary succession corresponds to fine sand and mud intercalations. Results point to deposition in subtidal conditions between the core base (ca. 2500 cal BP) and the 15th century (388 cm below surface). The dominance of marine foraminifera assemblages with high number of juveniles and high diversity index suggests an environment frequently under open marine conditions during this period. By opposition, the low δ^{13}C values, together with the occurrence of charophytes and reworked nannofossils (Cretaceous, Paleogene and Neogene) and foraminifera (Cretaceous), reflect the contribution of fluvial processes. This sedimentary record points to environmental conditions marked by changes in fluvial discharge and marine influence due to changes in beach morphology, i.e. alternate growth and erosion of a sandy barrier.
The accumulation of magnetic (heavy) minerals at the core base is the likely result of at least one high-energy event, occurred ca. the 1st century BC.
After the beginning of the Portuguese Ksar Seghir occupation (15th century AD), the sedimentation rate increases, silting-up the channel margins. Deposition occurs under low subtidal to intertidal conditions. Foraminifera assemblages point to low salinity, with coarse materials mostly constituted by minerogenic particles transported by the fluvial network. Changes in the sedimentary succession were detected between 219 and 140 cm below surface that, according to the age-model point to the 18th century AD and are possibly related to the 1755 tsunami.
Work funded by the Portuguese Fundação para a Ciência e a Tecnologia (FCT) I.P./MCTES through national funds (PIDDAC) – UIDB/50019/2020.

Application of acoustical and optical techniques in Underwater Cultural Heritage sites. Case study: Ancient Aegina Harbour

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In this study, we present a multidisciplinary, non-intrusive downscale approach for the documentation of Underwater Cultural Heritage (UCH) and paleo-landscape 3d reconstruction, implemented on the coastal area of Aegina Island, Greece, where one of the most extended submerged harbour complexes is preserved at least over the last 2.5 ka.

This approach succeeded in obtaining information that serves both geomorphological and archaeological purposes in a time- and cost-effective way, while obtaining information on centimetres to millimetres scale. Through marine acoustic devices, geomorphology and ancient submerged conical/linear rubble structures' morphometric parameters (geometry and terrain statistical parameters) were documented. Automatic seafloor segmentation techniques documented and verified known and unknown sites of archaeological interest. The spatial distribution of the structures revealed the construction of a well-planned harbour complex with multiple passages and different possible functionalities. The structures' morphometric analysis showed their preservation status, demonstrating the anthropogenic impact on the submerged ancient structures due to the modern harbour activity.

During the investigation, a Remotely Operated Vehicle (ROV) was utilized for the visual verification of the findings and the establishment of a 3D ortho-mosaic model of the site. Methods of image enhancement were applied to the ROV data aiming to reduce poor visibility conditions and mitigate the effects of light absorption in the water medium. The post-processing produced a more photo-realistic 3D photogrammetry model exposing the microstructure of the conical structures. Finally, the Multibeam Echo Sounding (MBES) data combined with the processed optical data produced a 3D explorable virtual environment of the submerged archaeological area. The 3d digital environments promote the UCH sites and allow their further exploration by experts and not experts in the field.

At present, Aegina is studying within the framework of Aegina Harbour city Project which is an interdisciplinary project focusing on the systematic study of the submerged and coastal archaeological infrastructure of the city harbour of Aegina. In addition, Aegina is one of the main pilot sites of the TECTONIC project which promotes the collaboration between professionals in the field of Underwater Heritage aiming to provide detailed and multi-disciplinary documentation to assess and improve techniques and methodologies for the UCH.

Reconstructing Holocene RSL changes in the Bay of Cádiz from stratigraphic records

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The Bay of Cádiz, located in South-western Spain (Andalusia Region), constitutes an example of a typical estuarine saltmarsh environment with a long human occupation affected by notable historical changes that have conditioned the sedimentary evolution of emerged and submerged zones. The Bay is constituted by two semicircular embayments and the sediment supply of the area is mainly related to the presence of the Guadalete River estuary in the northern one.

The aim of this study is to reconstruct the Holocene morpho-evolution and the relative sea-level change history of the study area by assembling a geodatabase standardized to the most recent international guidelines for RSL studies of geological sea-level markers (SLMs) derived from new boreholes and bibliographic data.

The SLMs interpreted as high-precision sea-level index points (SLIPs), based on the characteristics of the related depositional environments, were compared to a number of new glacio-hydro-isostatic adjustments (GIA) models to identify the main components which influenced the sea-level evolution and obtain the vertical displacement (VD) trends by using a Bayesian statistical approach implying Montecarlo simulations.

Comparing the resulting VD values, it is possible to assume that the whole area was affected by general subsidence related to the local sediment compaction which influenced the morpho-evolution of the different zones with a variable entity and completely outclassed the GIA-driven component.

In particular, the oldest data from the northern sector showed that the area was characterized by subsidence rates of about - 0.65 mm/yr between 6.7 and 3.0 ka BP. On the other hand, during the last 3.0 ka, the general trend appears to be homogeneous for both the main sectors of the Bay with an average subsidence rate of - 1.6 mm/yr.

Moreover, the interplay between new data from the boreholes and bibliographic sources allowed the realization of three sketches representing the morpho-evolution of the Bay of Cádiz during the last 6.0 ka BP, respectively related to 6.0-5.0 ka BP, 3.0-2.0 ka BP, and the present-day coastal configuration.

Quaternary sea level changes vs vertical movements in old Cape Verde volcanic islands

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The geomorphic evolution of volcanic islands, such as those of Cape Verde, is linked to vertical movements driven by the growth and decay of volcanoes as they move away from their genetic hot spot. The Older Cape Verde islands (Sal, Boa Vista, Maio) present a wide record of Quaternary marine terraces, the different arrangement of which can help to unravel the complex history of sea level and vertical movements in these particular settings. Information on the timing of this evolution may be obtained from radiometric (U-series, ^{14}C) and paleomagnetic measurements. Such volcanic islands evolve from an initial submarine growth stage, to final erosion and decay, through different stages: 1) Submarine growth – shoaling; 2) Emergence and shield building; 3) Erosion; 4) Rejuvenation; 5) Sinking and/or erosion. This last stage occurs in different site-dependent ways. In some volcanic archipelagos, the late subsidence leads to submersion and development of an atoll – guyot. Other archipelagos may show erosion under gentle uplift.

The general morphology and distribution of marine terraces in Sal, Boa Vista and Maio indicate that the islands underwent a general uplift, although with distinct rates, during the Quaternary. Sal Island presents an almost flat morphology suggesting an advanced erosional stage, whereas a few high elevation eruptive bodies (up to of 406m in its NE area) respond to a rejuvenation stage (1.06 to 0.6My; Holm et al., JGR 2008). The general morphology of Boa Vista indicates a younger erosion stage than that of Sal, as it has not attained the flatten stage. Its sedimentary environment is marked by islets and shallows, where Quaternary marine units developed. No younger volcanism marker of a rejuvenation stage has occurred so far. The general relief of Maio points to an even younger erosional stage, with a maximum elevation of 463m without any trace of rejuvenating volcanism either.

The general layout of the Quaternary marine terraces in these islands points to a general uplift during the Quaternary, slowing down towards the late Pleistocene, with the Last Interglacial marine units being generally close or even below present sea level, suggesting a recent inception of the subsidence stage.

Submarine terraced landforms and paleoshorelines of the Dalmatian islands in the Eastern Adriatic Coast, Croatia

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Sea level has changed significantly since the lower Pleistocene, with up to 135 m lower levels than at present. Periods of long-term standstills of sea-level could enable the formation of marine terraces. Bottom-current activity such as Complex Adriatic Sea water circulation can also induce a formation of terraced erosional features.
The investigated area is in the central part of the Eastern Adriatic Coast (EAC), in the SW part of the Žirje Island archipelago, at the eastern rim of the Mid Adriatic Deep. The archipelago is characterized by steep escarpments and submerged islands. The island geomorphology, with almost vertical SW island shores, is typical for the outer rim of the Dalmatian islands and extends to Telašćica and Kornati archipelago.
To detect the distribution and characteristics of submarine terraces, we used high-resolution acoustic methods – Multibeam Echosounder (MBES), Multibeam Backscatter (BSE) and Sub-bottom profiler CHIRP (SBP). The results of the extensive survey display abundant evidence of terraced landforms. The process of analysis involved the interpretation of SBP profiles and BSE data to differentiate terraces formed in sediment and those formed in carbonate rocks. Morphometric analyses of the MBES digital elevation model for terraces formed in carbonate rocks were made in the “TerraceM” software.
The resulting landforms recognized with TeraceM tools were detected at 96.8, 90.1, 81.5, 67.1, 63.1, 51.4, 36.2 and 26.1 m b.s.l. In addition, submarine terraces identified in SBP profiles were detected at 210, 195, 182, 176, 152, 128, 115 m b.s.l. Furthermore, progradational shoreline clinoforms were detected in multiple SBP’s at depths 128-130 m b.s.l., elevation indicative of Last Glacial Maximum (LGM) shoreline. These morphological features are erosional unconformities typical for shoreline progradation, whose rollover points (upper part of the clinoforms) mark the sea level position. They were detected at the slope towards the Mid Adriatic Deep in the submerged Krka River delta south of Žirje Island.
It can be concluded that detected submarine terraces were formed during MIS8, MIS6, MIS4/3 or MIS 2 (LGM) standstills, while LGM paleoshoreline was not previously detected along the EAC.
This work was supported by the Croatian Science Foundation project “QMAD” (HRZZ IP-04-2019-8505).

A 2400 year's record of volcanogenic ground deformations, coastal changes, and consequences for humans from Campi Felgrei area (S. Italy)

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This study aimed to assess the joint effects of ground deformation trends and anthropic forcing along the coasts of Campi Felgrei caldera, which is one of the most dangerous volcanos of the Mediterranean area, since the first Roman occupation.

A huge dataset of hundreds of archeo-stratigraphic boreholes was coupled with direct and indirect surveys of the main underwater archaeological sites scattered along the whole coastal area and the reinterpretation of bibliographic sources.

Clear evidence of a differential volcano-tectonic behaviour led us to divide the study area into three coastal stretches with homogeneous ground deformation trends. In each sector, a new relative sea level (RSL) curve was reconstructed, by interpreting our stratigraphic and archaeological data in terms of SL markers covering a wider timespan compared to the previous studies, from the first Roman urbanization to the present day. The comparison between RSL curves and GIA models allowed calculating vertical ground movements occurred along the coast with decimetric precision.

For each recognized phase of uplift or subsidence, we also studied the effects they had in terms of coastal geomorphological change, and advantages or negative impacts on ancient human activities. We measured an overall subsiding trend that brought the RSL from -12 m (4th century BC) to 7 m during three different episodes between 5th and 15th centuries, which was interrupted by short-lived falls of RSL. During the phases of RSL fall and/or volcano-tectonic stability, a basinward shift of the coastline created new emerged land even at the base of the local sea cliffs, where wide shore platforms emerged, favouring intense phases of urbanization on them. This trend also favoured the closure of the Lucrino lagoon with an extended spit bar during the 2nd century BC, allowing the establishment of a large oyster farming system by Sergio Orata. On the contrary, the subsiding phases resulted in the flooding of coastal areas and anthropic structures such as villas, nymphaea and ports inducing the construction of coastal protection works. In the extreme case of Portus Julius, subsidence led to the abandonment of the military port and its move to nearby Miseno.

Late Quaternary facies architecture of the Chienti River incised valley fill (Marche Region, Italy)

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An incised-valley system is composed of the valleys formed as a result of base-level drop and of its depositional fill accumulated during the following base-level rise. Reconstructing the stratigraphic record of incised-valley systems is an important tool for water resources investigation, reconstruction of pollutant distribution and for predicting the environmental effects of future sea-level rise.
In order to understand the impact of late Quaternary sea-level changes along the southern coast of the Marche Region (eastern central Italy), we reconstructed the stratigraphic architecture of the Chienti River valley fill.
High-density subsurface stratigraphic information was provided by a database of almost 500 boreholes, and by the recovery of two continuous cores, 23 and 46 m long, respectively. A detailed facies characterization was carried out through detailed sedimentological analysis, including grain size, colour, sedimentary structures, presence of plant remains or fossils, and carbonate nodules. The paleoenvironmental reconstruction was also supported by pollen and meiofauna analysis carried out on the core samples. Pocket penetration values were also collected on clayey and silty deposits to support facies interpretation.
A series of detailed stratigraphic panels oriented both parallel and transversal to the coastline highlights the 3D facies architecture of the valley fill: amalgamated fluvial-channel and floodplain facies associations dominate at proximal locations, whereas alternating fluvial-channel, floodplain, swamp, and beach deposits occur distally.
Reconstructing the stratigraphic architecture of the fluvial incised valley fill is a crucial requirement toward an effective three-dimensional representation of the aquifer systems and for delineating past climate changes. It is also an essential tool for successful environmental remediation, given that the study area being classified as a polluted site of regional interest since 2001.

The 4th millennium BC in light of the submerged sites at Ropotamo and Sozopol: Are there evidences for climate change?

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The 4th millennium B.C. on the Balkan peninsula is a period of great change, a transition from the Late Chacholitich to the Early Bronze Age cultures with a gap in the C14 dates of several hundreds of years. The archaeological records of those two cultures are very distinct. By the end of the LCA, there is evidence of a very complex social structure (Varna necropolis and tell settlements) the population of which relied mostly on agriculture with a vast network of connections and trade that spread from the Aegean all the way to Central Europe (the spondylus shells) as well as advanced metalworking and craftsmanship (again, the Varna necropolis). In comparison, the EBA can not be more different, flat isolated settlements with predominant stock-breeding traditions and a more mobile way of living.

Ever since the gap was identified there have been debates among scholars on the reasons for this drastic change in the way of prehistoric life. The most predominant being attributed to climate change and fluctuations of the sea level that were followed by a northern invasion that destroyed the LCA population.

With this archaeological background comes the rationale behind this research. That is to enrich our understanding of the 4th millennium BC on the Balkan peninsula by answering a very specific research question: Are there evidences of climate change in the submerged prehistoric sites at Ropotamo and Sozopol, if so what is their nature and how were the inhabitants of those settlements affected by it during the 4th millennium BC? The aim is to gather qualitative and quantitative data from submerged prehistoric sites that will give an irrefutable answer to that question. It will be done through underwater excavations with very a high-resolution documentation and interdisciplinary research. The results of which will be combined into a complete image of the past.

Interdisciplinary analysis of partially submerged pre-Columbian sites of Martinique, French West-Indies. Research issues, methodology and further perspectives

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In the actual alarming context of global warming and environmental change, all eyes are focused on the relative sea level rise and its catastrophic consequences. The impacts of this phenomenon on contemporary societies are extremely diversified. Among them the programmed disappearance in the coming decades of a large part of the coastal cultural heritage requires a specific reflection. The French West Indies are, because of their geographical position and their insularity, dramatically exposed to the coastal regression. This phenomenon of exposure to marine risks is not new. Since the last Pleniglacial period (18,000 BP), marine transgression is estimated to about +120 meters around the Caribbean basin. By developing a diachronic geoarchaeological approach to the material evidence of the submerged history of Martinique, we aim to determine the erosive and relative sea level processes behind the mobility of the shoreline as well as the relationship to the ocean of a corpus of three pre-Columbian deposits distributed on this territory. We will develop an original geoarchaeological methodological approach to the paleoenvironmental, taphonomic and predictive characterization of these sites, witnesses of the holocene land-sea interface in perpetual mutation. Thus, this holistic and unreleased approach in the pre-Columbian context of Martinique raises a plurality of research issues related to the prehistoric occupation modalities of this space. It must therefore fall within a solid methodological framework that must be reproducible on the scale of the entirety of the pre-Columbian submerged Antillean deposits. From sedimentary studies to three-dimensional paleoenvironmental simulations and from archaeologists to the actors of cultural mediation, a plurality of perspectives should emerge from our study which strive to contribute to an interdisciplinary archaeology of West Indies paleolandscapes.

Late Holocene submerged beachrocks in the Sea of Marmara (Tekirdag-Altinova, NW Turkey): Revealing tectonic uplift rate through LA-AMS dating technique

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Tectonically active coasts are dynamic environments characterized by the presence of beachrocks formed by the combined effects of wave erosion, tectonic uplift, and sea-level fluctuations at glacial-cycle timescales. The beachrock formations represent a significant paleo-environmental proxy because they are ideal marker horizons used for reconstructing past sea-level positions and revealing vertical uplift rates. Here in this study, it was used to assess the late Holocene coastline evolution of the northern Sea of Marmara.

The Tekirdag-Altinova coastal area is located in the tectonically active western Marmara Region. This tectonic activity is controlled by the North Anatolian Fault Zone (NAFZ) which played a crucial role in the coastline evolution at different periods of the region. This study aims to investigate the role of tectonic processes in the late Holocene evolution of the coastal landscape of the Tekirdag-Altinova area by assessing long-term vertical deformation rates. To document and estimate coastal uplift, beachrocks were used in conjunction with a novel laser ablation (LA)–accelerator mass spectrometry (AMS) technique and correlation to late Holocene sea level variations. In this study, we report the existence of the less known submerged beachrocks in the nearshore coastal area of Tekirdag city (Altinova), the northern Sea of Marmara. The beachrocks are distributed parallel to the modern shoreline with an extension of about 5 km and at depths ranging from -2 to 0 m below the present sea level. The well-preserved beachrocks have been identified and mapped using Unmanned Aerial Vehicle-UAV (a 5 cm resolution), sampled by the coring method.

Here, we present the novel LA-AMS system and apply it for the analysis of marine shells and calcite-cement of the selected samples from submerged beachrocks. The radiocarbon age results allowed us to correlate them with late Holocene sea-level high-stand and to estimate the long-term uplift rate. Based on the findings, an uplift rate of about 0.44 mm/year over the last 3000 yrs has been suggested for the study area.

Refined Geologic Mapping Reveals A More Complicated Depositional History of the US Mid-Atlantic Coast Since the Last Interglacial Period

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Located along the former glacial forebulge of the Laurentide Ice Sheet, the Delmarva (Delaware, Maryland, and Virginia) Peninsula (central United States Mid-Atlantic Coast) is composed of ancient coastal deposits (beaches, barrier islands, spits, etc.) formed during sequential periods of sea-level highstand throughout the middle to late Pleistocene. Subaerially exposed remnants of these coastal systems are prime targets for sea-level reconstructions and studies of glacial-isostatic adjustment (GIA) processes. Nevertheless, the sea-level history of this area remains unrefined. This reflects wide variability in the ages of dated coastal deposits and conflicting interpretations of their depositional environments. Here, we combine field sedimentology and stratigraphy (sediment cores ≤ 27 meters deep), subsurface geophysics (ground-penetrating radar and seismic profiling), and high-resolution topographic-bathymetric digital elevation models (largely derived from lidar) to produce a 1:62,500 map of ~300 km^2 of the central Virginia portion of the southern Delmarva Peninsula. Mapping is supplemented with geochronology based on infrared-stimulated luminescence dating and amino acid racemization. Our findings indicate that there are five distinct sedimentary sequences preserved in this region, each recording intervals when relative sea level was at or higher than modern mean sea level over the past 200 kyr; four of these post-date the last interglacial (120 ka). The internal geometry of each of these units reveals state changes between transgression (e.g., landward-migrating coastal systems) and regression (e.g., progradational beach and foredune ridges). Importantly, the youngest transgressive-regressive set—the newly mapped “Upshur Neck Member”—dates to ~55 ka, and was previously included in the “Wachapreague West” highstand depositional system (~70 ka) rather than as associated with a distinct period of highstand. This new interpretation improves our understanding of both the depositional history of this region and, by extension, its relative sea-level history. Further, our refined geochronology reveals a time lag during the last glacial period of 5,000–10,000 years between the onset of global sea-level highstands and the period of maximum local sea level along this ‘mid-field’ coast. This observation emphasizes the complex role of glacial geometry and associated forebulge uplift and subsidence in driving relative sea-level change along the U.S. Mid-Atlantic.

A review of the coastal and marine Pleistocene deposits of the southern Cape of South Africa

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South Africa is a far-field site with respect to global ice sheets, and as such, has remained unglaciated through the Quaternary glacial-interglacial cycles. This spatial setting means that geological deposits within the range of these sea-level fluctuations may be better preserved than other regions globally that were scoured by shifting ice sheets. The vertical range of sea-level change experienced in the late Quaternary of South Africa has generally been between ~10 m above present sea level in periods of warming, and ~130 m below present sea level during times of cooling. As sea level receded in response to glacial cycles, the continental shelf was exposed as a terrestrial landscape. In the southern Cape, within the Cape Floristic Region, this corresponds to an area the size of the country of Ireland. Across the present-day coast and continental shelf, despite the contrasts in the extent of exposure at different times, aeolianite and cemented beach deposits have been preserved that illuminate the nature of past coastlines and environments. Offshore of Mossel Bay, these have been mapped with high-resolution hydroacoustic methods (multibeam bathymetry, side-scan sonar and shallow sub-bottom profiling) and some have been sampled by scuba diving and sediment coring. Dating was carried out using Optically Stimulated Luminescence (OSL). Onshore-offshore correlation and comparison has been conducted between the now-onshore and now-offshore Pleistocene rock outcrops. There are distinct age clusters of aeolian and palaeosol deposits in large embayments, remnants on neo-coastal cliffs, and on the now-submerged shelf that broadly date to 90, 70 and 50 ka. Here we discuss land-sea connectivity, sediment supply, and preferential preservation of these deposits at specific times. We investigate the impact of ancient human use of these coasts, and how this analysis assists reconstruction of now submerged landscapes.

Present-day tidal notch elevation: the water level bias

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Tidal notches are believed to form roughly at mean sea level tide. with well-defined morphometric parameters compared to the reference sea level, and have been used as sea level markers for more than 150 years.

Through different field surveys, were observed on tidal notches cut along carbonate coasts from 73 sites in the central Mediterranean Sea, observing fauna and flora living in the tidal zone. Tidal notches genesis was correlated with wave energy, tidal range, lithology, and depth of the cliff foot.

In the campaign carried out in 2020, included in the Geoswim project, we investigated Lampedusa, the southernmost island in Italy (Pelagie Islands), 'anomalous' notches were observed compared to "regular" tidal notches usually observed in other areas. We discovered in two bays in the southern part of the island tidal notches constantly deepen in the inner part of the bays. Outside the bay, notches are at the usual elevation, while in the inner part of the inlets they deepen up to a maximum depth of about 30 cm below sea level and tend to narrow inwards. The same was recently surveyed on the southern coast of Gozo Island (Malta), within a narrow bay.

During the survey, time-lapse images were collected both above and below the water level, and the morphometric parameters of tidal notches were measured together with physical/chemical parameters, in particular temperature and electrical conductivity. A similar phenomenon was recognized and studied near Marseille (France) and published in 2017. Consequently, a comparison can be made for Lampedusa.

Literature and data collected confirm in all the studied cases the tectonic stability of the area up to MIS5.5. This, together with the rapid change of morphometric parameters within the bay allows us to exclude vertical tectonic movements of the coastline.

Tentatively, we hypothesize that a mix of hydrodynamic and environmental factors allows the formation of these anomalous notches. They occur under specific conditions of wind, waves, and morphology of the coastline that can lower the elevation of maximum erosion rates, slightly below the mean sea level in sheltered areas.

New chronology scenarios for submerged relict paleoshorelines and associated uplift rates offshore Marzamemi village (Southern Sicily)

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Eastern Sicily, along with the Calabrian Arc region, is one of the most tectonically active regions of Southern Italy. Indeed, the tectonic setting of SE Sicily has been adequately studied. The study area of this work is located offshore Marzamemi village, SE Sicily, and it represents the emerging portion of the NE-SW oriented bulge of the African foreland. During June 2021 we performed a multibeam echosounder survey thanks to which we were able to produce a new 17 km2 high-resolution bathymetric map. From a geomorphological point of view, investigation of such an area resulted in the discovery of several relict marine terraces, identified through the mapping of paleoshorelines. These terraced landforms are largely used to reconstruct the Quaternary glacial and interglacial climates, marking different phases of sea-level variations through time. The mean regional uplift rate of this area is of about 0.2 mm/yr since Tyrrhenian time. Despite studies of onshore marine terraces have shown that uplift rates remained constant through the whole Late Quaternary, they have a tendency to vary spatially; higher uplift rates have been observed in the Augusta's area (about 0.41 mm/yr), decreasing southward along the coast. This would suggest a sort of tectonic stability moving even southward, thus in the Marzamemi area. The aim of this work is to (i) trying to refine the chronology of the mapped submerged paleo shorelines, (ii) refining the associated rates of uplift, and (iii) speculate hypotheses on the significance of these offshore preserved marine terraces compared to what is known in the literature in respect to uplift rates, tectonic regional setting, and sea-level variations. Specifically, here we propose two possible scenarios resulting from the application of the synchronous correlation approach, driven by already published age controls.

Reconstruction of the paleo-landscape of Ognina (Siracusa, South-eastern Sicily) during the occurrence of tsunami and storm events

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South-eastern Sicily represents one of the Mediterranean areas most impacted by tsunamis and storm events in the past. These extreme marine events left geomorphic and sedimentary imprints, such as large boulders or high-energy deposits, along the coasts. One of these deposits was reported by previous works along the coast of Ognina, a small residential area located 20 km south of Siracusa. The deposits fill the back edge of a ria incised into Miocene limestones, and are composed of three main stratigraphic units attributed to several tsunami and storm events that occurred along the coasts of south-eastern Sicily since the IV century Common Era (CE). In this work, we use numerical models to simulate the impact of these extreme marine events, at the time of their occurrence, along the Ognina coastal sector, with the aim to: i) better define the tsunamigenic sources responsible for the events found in the deposits, ii) verify if some units could be related to a storm event, iii) investigate constrains on the paleo-landscape of the studied area at the time of tsunami and storm occurrence. We reconstructed the morphology of ancient local landscapes using geological and historical information, together with a detailed topographic and geoelectrical survey. We implemented a modelling chain to simulate the tsunami and storm wave propagation upon the ancient landscapes. Our results highlighted that the use of advanced modeling tools, combined with in situ geological evidence and geophysical survey, has the potential to support the attribution of coastal geomorphic imprints to specific tsunami or storm events, the better definition of the paleo-landscapes, and the identification of the most likely tsunamigenic sources. This last aspect plays a fundamental role in providing more reliable characteristics of the tsunami propagation as well as in the assessing of potential tsunami hazard and related coastal impacts.

Session 44: Environment-human interfaces, new frontiers of consilience in the reconstruction of the past

Unconventional archives of human-environment interactions from Maharashtra, India

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Globally, there is a need to better characterize human-environment interactions as we strive to meet the pressing demands of a changing climate and work towards a more sustainable future; this is especially true for areas that have been pronounced “climate hotspots.” Maharashtra, India, one of these hotspots, is both a critical agricultural hub and a region that experiences pronounced and well-documented impacts of anthropogenic climate change. Combined with rapid population growth, expansion of water intensive cash crop agriculture, and urban development, these droughts have emerged as major stressors on freshwater resources in the region. This combination of factors has led to large-scale social disruptions, including crop failures, rural-urban migration, and farmer suicides. Maharashtra, therefore, provides a perfect case study for characterizing human-environment interactions in the “Anthropocene.”

While long-term climatic reconstructions exist for Maharashtra, there are few records of changes in the human-environment system on timescales of human interest and on localized geographic scales. Here, we investigate the use of unconventional sediment archives – sediments from human-made reservoirs – to determine if they can provide critical information about local climatic and ecological systems through the Anthropocene. We have found that the high-resolution (inter-annual) records preserved in these cores contain records of depositional changes (e.g., sediment grain size, magnetic susceptibility) that can be useful in understanding hydrological changes. We note that regional expressions of the summer monsoon, which may deviate from regional-scale climatological records, are recorded in these cores, providing us with both higher-resolution temporal and geographical records of environmental change and variability. Other proxy records in these cores promise to provide similarly high-resolution records on environmental change within the local watershed and the lake itself. When interpreted in consilience with historical records, these environmental records can provide a context of human interactions with their freshwater ecosystems that can help us better predict the future of these interactions in a changing world.

Past climatic conditions of Northeasthern Nunavik (Canada): Wind and atmospheric temperature from historical sources

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Northeasthern Nunavik, like many Nordic environments are facing climatic changes that have major impacts on physical and human environments. Ice melting and temperature rising have many consequences in communities of the North, mobility on ice become a challenge, fauna and flora are changing. To better understand the changing climate, it is important to rely on data from the past. Unfortunately, meteorological data are only available since 1929 in Quaqtaq, and are discontinuous until 1980. The objective of this research is to provide information on past atmospheric temperature and wind conditions based on instrumental, documentary and narrative sources. This work is focusing specifically on land records from southern Hudson Strait, a west to east axis including Kangiqsujuaq, Quaqtaq and Killiniq. Series of instrumental temperature record are available since 1883 until now. Wind strength and direction was extracted from 2 sources: three reports of a Hudson Bay meteorological expedition (1883 to 1886) and post journals of the Hudson Bay Company (1914 to 1940). During the first period, predominant wind was blowing from the north-west (33%), the west (17%) and the north (17%) with south-eastern winds during spring (11%) and eastern winds during summer and autumn (respectively 17% and 10%). The second series showed annual predominant winds from the north (29%) and the west (17%). A temperature index was built based on narrative sources, including travel journals, life stories and novels. The five-point index (-2, -1, 0, 1, 2) distinguished a summer and a winter signal. It shows that winters colder than normal are generally associated with predominance of the west (33%) and the north (27%) winds, with further numbers of very strong winds. Summers warmer than usual were usually described with light winds from the east (34%) and the south (23%). Reconstructed temperature record appears to be in concordance with regional atmospheric circulation patterns notably the North Atlantic Oscillation (in opposite relationship for this region of the North Atlantic).

Interweaving narratives: Understanding the dynamics of human-environment relationships in the Maya region

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Despite extensive research, the relationship between climate change and human societies is still not well understood, especially with respect to how and to what extent climate change can be considered a primary driver in the cultural trajectory of a particular region. Although there are new analytical opportunities provided by methodological developments in various disciplines, little is known about the short- or long-term dynamics of past human-environment relationships. Reasons for this include a lack of, and challenges in, integration between relevant fields, such as archaeology, anthropology, epigraphy, palaeoclimatology and palaeoecology. This paper explores how integrating datasets from different disciplines can lead to a better understanding of the socio-ecological relationship between human societies and their environments and how this drives cultural change.

The paper focuses on the Maya society, whose perceived successes and failures are often linked to their relationship with the local environment and their response to episodes of climate change over a period of nearly 2000 years. The works responds to recent debates and new analytical opportunities in Maya studies, provided by developments such as increased volume of paleoclimatic data, the growing field of settlement archaeology and advances in Maya epigraphy.

An increased interest in climate change within the last few decades has meant that a large amount of paleoclimatic data have been collected from the Maya area, often indicating considerable changes in rainfall patterns during the mid-to late Holocene. These data, beside other things, challenged the general assumption of unproblematic water supply in the tropics. The ethnographic research conducted among contemporary Maya communities supports this new outlook; it showed that "drought" and especially high variability in rainfall patterns are real phenomena with often severe consequences for people's livelihoods. Combined with archaeological and epigraphic evidence, the results also confirmed that both ancient and modern Maya developed a wide variety of strategies to cope with extreme climate events; as well as to adapt to changes in the long run.

By combining range of evidence, the paper looks at the relationships between Maya society and the local environment, on multiple spatial and temporal scales, while also considering socio-cultural agencies.

What can climate-forced vegetation modelling and pollen-based reconstructions tell us about anthropogenic impact on European vegetation of the Holocene?

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Assessment of past anthropogenic modifications of landscape dynamics is crucial for understanding the human role in Earth systems, especially to question the natural state of the system. Recent advances in paleoenvironmental sciences allow us to assess the long-term impacts of anthropization on ecosystems, landscapes, and land cover.

Our study, conducted within the framework of the EU-ITN TerraNova project (https://www.terranova-itn.eu/), aims to combine pollen-based vegetation reconstructions and vegetation modelling to highlight the relationship between vegetation changes and anthropogenic activities in Europe throughout the Holocene.

The method is based on a comparison between modelled and reconstructed vegetation cover over 15 time windows from Mid-Holocene to the present day at a 1˚x1˚ spatial resolution for Europe. Modelled vegetation is derived from climate-forced vegetation modelling, using a dynamic vegetation model (CARAIB) forced by the downscaled version of the iLOVECLIM climate model, and represents potential natural vegetation of the past. Climatic variables, derived from the iLOVECLIM are bias-corrected using the cumulative distribution functions transformation (CDF-t) method. Pollen-based reconstructions are obtained by applying the 'Regional Estimates of VEgetation Abundance from Large Sites' (REVEALS) model on pollen records to reconstruct observed vegetation cover across Europe for the last 6.5 ka years.

The comparison is performed using presence fractions for 9 plant functional types, calculated by CARAIB and REVEALS independently. Analysis of the evolution of discrepancies in two datasets allows us to distinguish the role of climatic conditions in pollen-based vegetation reconstruction from other types of impact. The results of our study indicate that the proposed methodology effectively offset the impact of climatic conditions on pollen-based vegetation reconstruction, which allows us to estimate the possible role of anthropogenic factor in European vegetation distribution change over the mid- and late-Holocene.

Further research steps, made in collaboration with other partners of the TerraNova project, will include incorporation of both vegetation datasets in an agent-based model, aimed to assess the role of hunter-gatherer activities in vegetation changes, incorporating anthropogenic land cover change scenarios to the workflow and introducing plant consumption by megafauna, which will allow further analysis of underlying processes behind landscape changes.

“Smoky forests” - The legacy of charcoal production in pre-industrial Central Europe

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The human activities related to land use accompanying agriculture have been the main driving force behind the formation of new landscapes. On the other hand, the role of other factors affecting landscape transformation has not been fully identified. Forests, in particular, were exploited not only for timber, but also for other wood-related products (such as charcoal, potash, and tar), but the spatial scale of this activity and its effects are not yet recognized. Charcoal was a very important economic and energetic resource during the pre-industrial period. This is underlined by the fact that, so far, we have mapped more than 600,000 remnants of charcoal hearths in Central Europe. As time progressed, the demand for energy increased until coal began to be used on a wider scale in the late 18th and early 19th centuries. Our goal is to provide a comprehensive understanding of how charcoal hearths functioned and to state what role they played in the evolution of landscapes. For this purpose, research methods typical of biogeography, remote sensing, dendroecology, paleoecology, soil science, botany, onomastics, as well as art history were combined in order to thoroughly understand not only the natural consequences but also the social and economic aftermath of charcoal production. Our paleoecological results show intermediate disturbance connected with charcoal hearths operation affecting the short-and long-term changes in the ecosystems, which had a cascading nature. Charcoal production causes severe consequences to vegetation composition, soil properties, microclimate, water cycle, and finally erosion that, in turn, affects adjacent lake and peatland ecosystems. This research addresses the emerging issue of the impact of charcoal hearths legacies of past human activity and the effect of shaping the trajectory for landscape transformation during the pre-industrial period.

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Historical forest management in central Europe: a multiproxy approach combining tree rings and pollen-based land cover modelling

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Throughout history, humans relied on wood for constructions, tool production or as an energy source. Historical timber is therefore a great source of information for studying land use changes related to wood utilization and forest management, which provides further insights into the impact of land use on vegetation and plant diversity over the last millennia.
Here, we focus our study on the last 1000 years and Central Europe. 44 240 precisely dated tree-ring samples from the economically and ecologically most important tree species (spruce, fir, pine, oak, beech) found in historical buildings were compiled and analysed regarding their dendrological characteristics. In parallel, pollen records from 205 sites were used to quantitatively reconstruct the regional plant abundance (25 plant taxa) for a total of 45 1° by 1° grid cells; the REVEALS model is used to transform pollen data into regional plant cover. The different cells were compiled according to their average elevation, lower (below 500m asl) and medium elevation (above 500m asl). Results of both proxies were compared at a temporal scale of 100-year time windows. Our results show that during the period 1150–1850, a steady decline in forest cover and an increase in open land were observed. Land use changes overtime were recorded. At the same time, phases of higher (e.g., after the Thirty Years' War (1618–1648 CE)) and lower (e.g., during the Black Death (1346–1353 CE) and during the Thirty Year's War) building activity were observed. Furthermore, equivalent amount of spruce and oak were used as construction timber, respectively 35% and 32%, whereas conifers overall dominated the wood in buildings. Most strikingly, the diameters of the trees at the time of harvesting were similar (about 25 cm) for all four species (spruce, fir, pine and oak), while the age and growth rate varied, indicating a selection of wood based on the diameter criterion throughout the period.
This study reveals that human selection of suitable trees for timber construction based primarily on tree species and diameter coupled with exploitation policy resulted in changes in plant abundance and forest structure.

Understanding the relationship between humans and the coastal environment in the deep past: the consilient approach of SPHeritage Project

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An interdisciplinary approach is necessary to investigate the relationship between human peopling and the coastal environment during Prehistory. We present the challenges faced and the strategies adopted in the framework of the SPHeritage Project, which aims to understand how Palaeolithic groups living along the Ligurian-Provençal coastal area, in the NW Mediterranean, responded to Pleistocene sea-level fluctuations and the related changes in the littoral environment. The Balzi Rossi study area contains a unique complex of Palaeolithic sites of archaeological significance, as well as sea-level indicators of the last 3-4 interglacials, within a rocky coast geomorphological setting.The evidence of Palaeolithic settlement and exploitation of marine resources provides opportunity for the study of human adaptation associated with sea-level change.

A number of major challenges had to be tackled, though, to achieve the goals of this Project. Large portions of the local archaeological sequences were removed in earlier investigations that began at the end of the nineteenth century, during which time an integrated approach of natural and human sciences was lacking. Moreover, a standardized assessment of the palaeo sea levels had never been performed in the area, hampering the possibility to reconstruct the geographical and ecological characteristics of the environments associated with early human settlements. Finally, the age constraint of the investigated sequences was mostly based on old technologies, with consequent limitations in reliability and accuracy of chronology.

The strategies adopted to overcome these issues were based on the synergic work of a multidisciplinary team with diverse expertise. Strategies included novel stratigraphic correlation between sites, new and extensive age constraint of the marine and terrestrial deposits using multiple and innovative methods, and the detection of past shorelines on the continental shelf through geophysical surveys and sediment coring.

Our preliminary data are promising, and suggest that a cosilient approach can provide valuable insight on how relative sea-level change and consequent shoreline fluctuations can drive settlement strategies and human migration/dispersal patterns.

Session 45: Plants as Resources for Early Humans – Availability and potential exploitation of useful wild plants through Pleistocene human history

PlantBITES – A database for Plant Resources in Early Human Environments

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Studies on possible plant food and its availability for different groups of early humans so far usually consider only a pre-selected set of plant species often based on the scarce archaeobotanical record. In contrast, the database PlantBITES is a tool to consider the full range of potentially available, dominant plant species in vegetation units. It serves assessing the amount and variety of obtainable food (and other) resources for early humans. Data collected in PlantBITES comprise information mainly on edibility and other uses of plants that occur in natural environments as well as their relevant botanical traits. Based on such records it is possible to analyze and quantify plant resources and their seasonal availability for humans in a given environment.

The availability of plant resources is considered taking into account not only natural aspects but also the different levels of cultural capacities necessary for the utilization of plants – as it is usually not included in ethnobotany. Cultural capacities of different hominin groups regarding the exploitation of plant resources change considerably through time with respect to the use of tools and fire, and especially the capability to process and store plant materials. Therefore, the PlantBITES database facilitates the evaluation of the relevance and impact of climate or other environmental changes as well as of cultural developments on the resource availability for early humans through time.

PlantBITES provides a range of applications for exploring the resource space of early humans. This will be highlighted by examples of exploring the database to quantify the spatial and seasonal availability of plant food resources for early *Homo* in the South of the Iberian Peninsula, as well as the availability of plant food resources in relation to changing cultural performances of early *Homo* in Southern Africa.

First evidence of plant use in Tagua Tagua 3, a Late Pleistocene site in central Chile: Cultural and environmental implications

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The ancient Tagua Tagua Lake is one of the oldest archaeological localities in central Chile (34S), with at least three well-controlled late Pleistocene anthropogenic deposits. The hunter-gatherer tradition of its inhabitants has been well documented. However, the scarce preservation of organic evidence in central Chile has mostly prevented the study of plant resources of these early occupants.

In this contribution we present the first evidence of plant remains from the archaeological site Tagua Tagua 3. We study the stratigraphic sequence of phytoliths in the sediments throughout the occupation, spanning from the Late Pleistocene to the beginning of the Middle Holocene. In addition, we focus on the plant micro and macro fossils recovered directly from the earliest occupation of the site. We studied plant microfossils gleaned from seven lithic artifacts, whereas the macrofossils correspond to charred seeds recovered from a hearth dated c. 12,500 cal BP.

Our results show an evolution of the vegetation landscape through the occupational sequence that is complementary to pollen studies and new sedimentary biomarker analyses carried out on the site. Preliminary results of cultural evidence show an assemblage of microfossils composed of highly fragmented phytolith, starch grains, trichomes, pollen and indeterminate plant tissue.

Five artifacts showed evidence of plant use, including geophytes (typically rich in starch) and leaves of cf. Nicotiana sp. In addition, remains of feathers were found in one of the sharp-edged flakes, implying that these instruments were versatile. The material recovered from the hearth provides new insights into the cultural uses of plant and animal species, but also into the prevailing environmental conditions. Despite its small volume, the rich assemblage recovered shows a surprising diversity of plant species that can be linked to the bones of micro and megafauna, insects, eggshells, and possible remains of ostracods that were also recovered.

This new evidence shows the need to expand our records of local reference collections for the study of the plant remains. Comparison of our results with synchronous occupations will be of vital relevance for understanding the uses of plant resources by these early hunter-gatherer groups of Tagua Tagua and South America.

Early hunter-gatherer sites in the Atacama: living under the trees in the most arid desert in the world, 13,000 - 11,200 cal BP

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Humans arrived in the Atacama Desert 13,000 years ago, facing one of the harshest landscapes on Earth. They settled in a rainless stretch of land with scattered patches of biotic resources fed by increased rainfall in the Andes. They established social networks with people from different environments, creating essential bonds to maintain viable populations. However, we do not understand how they inhabited this forbidding landscape to make it their home. We propose that, aside from water sources, groves of phreatophyte trees, especially *Prosopis tamarugo*, were important when choosing locations for residential camps. These trees not only provided shade and endured droughts but fostered a more fertile environment by improving soils and attracting fauna. These groves would also have been visible landmarks in an otherwise barren landscape, promoting social aggregation. Based on ethnographic data, soil analyses, taxonomic identifications, and over 100 radiocarbon dates on preserved *in situ* tree stumps and charcoal associated to Paleoindigenous sites, we propose that the first peoples of the Atacama did not always interact with trees through exploitative ways. We posit that Paleoindigenous peoples of the Atacama made efforts to preserve a specific genus of tree: *Prosopis*, preferring other species for firewood and tools (e.g. *Schinus molle*), transforming the enduring *Prosopis* groves into focal points for inhabiting the Atacama both by the end of the Pleistocene and the beginning of the more hyperarid Holocene. To our knowledge, this is the first study that presents preserved evidence of tree groves contemporaneous with early (i.e. Paleoindigenous/Paleolithic) hunter-gatherer sites in the world.

Vegetation reconstruction and plant food availability for Homo sapiens in the highlands of Ethiopia since the Last Glacial Maximum

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The Ethiopian highlands are a hotspot of archaeological and palaeoenvironmental interest as they have potential to shed light on the Late Pleistocene and Holocene cultural evolution and expansion of *Homo sapiens*. A number of archaeological sites in the SW Ethiopian mountains provide evidence of discontinuous occupation over the last 22 ka. In order to identify possible links between humans' dispersal across the region and past environmental habitats it is crucial to understand how plant ecosystems changed since the Last Glacial Maximum (22 ka BP). To do so, we have modelled past vegetation distributions in Ethiopia using detailed maps of modern potential vegetation combined with high-resolution palaeoclimatic data. The modelled distributions show significant changes in the extent of the main vegetation units through time which are validated by regional pollen records. One of the most remarkable findings of the simulated vegetation distributions is the expansion of areas with high climatic suitability for Afromontane forests during the late glacial. This inference is in contrast with long-standing hypotheses that suggest that savanna and grasslands became more predominant in the Horn of Africa during the Last Glacial Maximum. The series of vegetation belts that nowadays characterise the south-western Ethiopian highlands are estimated to have migrated downslope between 500 and 600 m during cold periods of the Late Pleistocene. We are aiming to assess the impact that the altitudinal shifts and the geographic distribution of vegetation units may have had on the amount and variety of food resources available for human populations inhabiting the Ethiopian mountains. An extensive database currently under development (*Plant-BITES*) compiles information on the edibility, nutritional value, accessibility through the year and other uses of plants that occur in each vegetation unit. The combined analysis of the availability of plant resources and the pattern of occupation of the montane archaeological sites show the relevance of habitats distribution to provide suitable settings for occupation to humans in the region throughout the last 22,000 years.

Use of plants for medicinal and edible purposes during the Upper Paleolithic and Neolithic Period in the territory of Georgia according to palynological research

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The palynological research of the cultural layers of 4 Upper Paleolithic caves (Dzudzuana, Satsurblia, Kotia Klde and Bondi) and two Neolithic settlements (Gadachrili Gora, Shulaveri Gora) in the territory of Georgia showed that people of that time used dozens of fruits, seeds, leaves, shoots and bulbs of plants in their diet and medicine.
As the researched material shows, in the Upper Paleolithic people store supplies in caves, where they often kept nuts (*Corylus*) and wild cereals (Poaceae), the pollen of which always prevails in the layers of the cave where they lived. Palynological research showed that at that time people ate beech (*Fagus*) fruits, picked wild grapes (*Vitis silvestris*), constantly consumed walnut (*Juglance regia*) and chestnut (*Castanea*) fruits, collected horsetail (*Hippophea*), asquil (*Roza canina*), cornus (*Cornus*). From grasses, in addition to cereals, *Malva*, *Plantago*, and *Carduus* were used as food.
As for medicinal plants found in the Upper Paleolithic cave materials, people used several antipyretic and anti-inflammatory remedies, such as lime (*Tilia*), which is still used in phytomedicine today. In the list of medicinal plants, there are also many pollen grains of pain-relieving and anti-bleeding plants, such as *Centaurea jacea*, *Ephedra*, *Campanula*, *Trifolium* and others. During the research of the Upper Palaeolithic samples, a total of 32 medicinal plants were identified.
In the Neolithic Period, the human diet improved as it began to cultivate cereals and other plants, and folk medicine developed more. Compared to the Upper Paleolithic, the Neolithic people studied and consumed much more medicinal plants. 56 medicinal plants have been identified from the Neolithic layers, almost twice as many as from the Paleolithic.
The study of material from the Upper Palaeolithic and Neolithic periods clearly illustrates the Neolithic revolution, which is manifested by a radical increase in food and medicinal plants in the archaeological material.

Vegetation dynamics and the origin of proto-cereals in Eastern Mediterranean from pollen and NPPs during the last 3 Ma: the case of Lake Acigöl and Lake Burdur in Turkey

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The Eastern Mediterranean is a key region on the crossroad between Europe, Asia and Afrique. The first hominins are out of Africa at least around 1.8 Ma and the Eastern Mediterranean is the cradle of agriculture at the beginning of the Holocene and a major center of crop plants diversification. The domestication of Poaceae by humans and thus the apparition of cereals is attested at around 11,000 years BP in the Fertile Crescent. However, the presence of pollen of Cerealia (proto-cereals) is attested in Lake Acigöl, South-Western Turkey, between 2.3 Ma and 10 ka. As proposed in previous work, the appearance of proto-cereals could be linked to the pressure of large herbivore herds on steppic ecosystems around the Lake Acigöl, leading gene mutations of Poaceae. Proto-cereals and other edible plants from Acigöl may have been part of the diet of early hominins present in South-Western Turkey between 1.6 and 1.2 Ma.

In the framework of the ANR project FOOD-RE, the BS 87 series of Lake Burdur, located at around 30 km West of Lake Acigöl, is currently being studied. The aims of this study are to (1) reconstruct the vegetation dynamics based on pollen between 3 and 2.5 Ma around the Lake Burdur to complete the previous study carried out on Lake Acigöl between 2.3 Ma and 10 ka (2) identify pollen grains of Cerealia-type and perform measurements (3) understand more precisely the mechanism at the origin of presence of pollen of proto-cereals in this area.

The first analyses show an open landscape dominated by a steppe Poaceae, *Artemisia* and Chenopodiaceae. Pollen of proto-cereals have been also recorded before 2.5 Ma and measurements of pollen grains show large grain size, annulus and pore diameter. The mechanisms of the apparition of pollen of proto-cereals will be analyzed and compared to coprophilous spores and mammalian fauna in South-Western Turkey.

Setting the table in Sangiran: Availability of food resources for Hominids in Java at 1 Ma

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This study focuses on available edible resources for hominids in Sangiran by the time of the Grenzbank formation. At that time at least two hominids, *Homo erectus* and *Meganthropus paleojavanicus*, inhabited the Sangiran area. These hominids differ in their dentognathic morphology and therefore presumably in their dietary strategies. In order to reconstruct the diet composition of both kinds of hominids, the reconstruction of the available resource space is crucial. Do their diets differ due to the exploitation of different vegetation units? Or does the difference relate to physiological or socio-technological factors? This study establishes the basic framework to answer these questions.
We identify five distinct vegetation units within a 50 km radius around Sangiran. These units are reconstructed on the basis of palaeotopographic and climatic maps. The majority of this area is covered by Lowland Monsoonal Forest (LMF) and freshwater habitats.
The resource space includes all edible resources and is divided into five categories: plants, insects, aquatic resources, as well as small and large vertebrates. The actual diet of hominids comprises a selection from the resource space based on the abundance and seasonal availability of resources on one side and the socio-technological skills of hominids on the other side. A rare resource, which is only available during few months of the year is less likely part of the diet than an abundant aseasonal resource. If this resource requires for instance heat treatment to be consumable, only hominids with the technological skill to use fire can include this resource into their diet.
Therefore for every edible species in each vegetation unit data on abundance, seasonality and required processing are collected. In this way the different vegetation units can be compared in terms of their resource availability of each category in the dry and wet season. The LMF for instance offers more fruits in the dry season than in the wet season, but more edible plant parts in total than freshwater habitats.
In this way, we describe and analyze the resource space of hominids at Sangiran and provide insights into resource availability and potential subsistence strategies of *Homo erectus* and *Meganthropus paleojavanicus*.

Session 46: Application of biomarkers and CSIA in Pleistocene archaeology

Plant-wax biomarkers in the Quaternary sediments of Deserts: Implications for human-environment reconstructions

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The preservation of plant-wax compounds over millions of years has provided an opportunity to develop fresh insights into past climatic and environmental conditions. These compounds have been found to be well-preserved in a wide variety of archaeological and palaeoenvironmental sediments. Temperate palaeosols and lake sediments have shown particular promise for preserving plant-waxes. However, the potential of plant-wax biomarker analysis in desert environments has yet to be explored, with general assumptions that these compounds, and organics in general, would be less likely to be preserved in sandy sediments, while low abundance of vegetation on the landscape would further minimize expected concentrations.

In this study, we evaluate the preservation of straight-chain alkyl lipid compounds such as *n*-alkanes and *n*-alkanoic acids (fatty acids) in desert sediments collected from 4 different archaeological sequences in the Nefud Desert, Saudi Arabia (n=2) and in the Thar Desert, India (n=2). The Nefud and Thar Deserts are selected given that they are geographically situated on one of the pathways of human dispersals from Africa to Asia, making them important sites for studying past human-environmental interactions. The samples were selected to represent both the Pleistocene and Holocene epochs to facilitate study of the effects of age on the preservation of these compounds.

We studied the preservation of plant-wax biomarkers using distribution patterns, carbon preference indexes (CPI), average chain lengths (ACL) and compound concentrations (ng/g dw). We also analysed samples for bulk $\delta^{13}C$ values and total organic carbon (TOC, %) to understand organic preservation and dominant vegetation contributors to the plant-wax organic pool in these desert environments. The results of molecular indices such as high odd over even preference (OEP) in *n*-alkanes, even over odd preference (EOP) in fatty acids, high CPI (Alk≥2.9 and Acid≥4.4, and high ACL (Alk ≥29.9 and Acid ≥27.4) indicate that plant-wax compounds are well-preserved across the studied desert sequences. This study provides a platform for applying this methodology to contexts where the impacts of climate and environmental change on past human societies during the Quaternary period is a question of high priority.

Plant Wax Biomarkers Reveal Late Pleistocene-to-Holocene Climatic and Ecological Change and Afromontane Human Adaptations in Lesotho, Southern Africa

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Archaeological and paleoecological studies seeking to understand the climatic and ecological conditions associated with human expansion into African montane environments are often limited by a lack of proxy data obtained directly from archaeological sites. Although numerous proxy archives exist for southern Africa for the Quaternary, many of these are distal to archaeological sites (i.e., off-site) and obscure the ecological complexity that on-site records can provide for areas of past human activity. Here we present a ∼58-thousand-year vegetation and precipitation record using molecular $\delta^{13}C$ and δD values of plant wax *n*-alkanes directly from archaeological sediments collected at the Ha Makotoko rockshelter in western Lesotho, which extends from Marine Isotope Stage 3 through to the Holocene.

Stable carbon isotope ratios from terrestrial plant wax biomarkers indicate a constant C_3-dominated ecosystem from ∼58 to 5.0 ka, followed by C_4 grassland expansion due to increasing Holocene temperatures. Meanwhile, hydrogen isotope ratios indicate a relatively wet later Holocene compared to a drier, yet stable, Pleistocene and early Holocene. The results from Ha Makotoko demonstrate that the resource-reliable, Pleistocene environments incentivized persistent upland habitation likely due to generally uniform precipitation and dependable freshwater reserves that supported rich terrestrial food resources along perennial water courses. The added ability to catch fish may have underpinned the ability of hunter-gatherers to survive in highland Lesotho by compensating for significantly reduced availability of terrestrial plant foods when colder conditions prevailed. In particular, our data contributes to debates concerning the adaptive capacities of humans in upland environments and how they may have acted as key refugia or conduits for the biogeographic dispersal of humans during periods of climatic stress that impacted lower-altitude biomes.

One Toba, Different Tales: Assessing variability in environmental impact of ~74ka Toba super eruption on South Asian mosaic

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The ~74ka Toba eruption is considered the largest explosive volcanic event of the last 2 million years, with a Volcanic Explosivity Index (VEI) of 8.8. It is thought to have caused global havoc, leading to drastic global cooling and population bottlenecks for many species, perhaps including humans. Many global climatic records and simulation studies have shown that ~74ka Toba eruption had severe impact on the northern hemisphere and may have affected hyper-arid zones of southern hemisphere as well. Current research is framed around the idea that Toba event had highly variable regional environmental impacts, and regions such as South Asia may have been completely unaffected despite their relative proximity to the eruption. Nevertheless, the manifestation of Toba on local environments in South Asia has been difficult to explore due to a lack of chronometric ages and terrestrial environmental record. Our current work focuses on the well dated YTT sequences from central, western and Southern India, and seeks to create a paleoenvironmental transect to explore Middle-Late Pleistocene environmental change and the possible impacts of the Toba eruption across different biomes in South Asia. To do so, we employ analysis of plant wax biomarkers (n-Alkane) and compound specific isotopes ($\delta^{13}C$ and $\delta^{2}H$) for assessing paleovegetion and paleohydrological responses and subsequent habitat transformation. Our novel biomarker records promise the possibility of more detailed insights into the environmental change encountered by human populations in South Asia at the time of the Toba eruption and the Late Pleistocene more widely.

Palaeoenvironment during the Middle Stone Age in interior South Africa based on n-alkane stable isotope records

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The Middle Stone Age (MSA) between 300 and 30ka in southern Africa is associated with complex cultural innovations by anatomically modern humans. While archaeological sites in caves and rockshelters along the coast provide a MSA cultural record predominantly after 160ka, sites in the Kuruman Hills in the arid interior of South Africa have evidence for occupations that focus on the earlier part of the MSA. Associated palaeoenvironmental records show wet phases during these occupations at Wonderwerk Cave, Kathu Pan and Ga-Mohana Hill rockshelter based on reconstructions using sediments, tufas and organic remains. However, beyond these exceptional sites, organic preservation is rare in the southern Kalahari during the Pleistocene. Sediment biomarkers are an innovative method that can create palaeoenvironmental records directly at archaeological sites, in addition to or despite of the lack of other suitable proxies. Leaf wax n-alkane records, tracking changes in the proportion of C_3 trees with C_4 grasses, are particularly promising biomarkers to study in the savanna environment of the Kuruman Hills. We present n-alkane carbon and hydrogen stable isotope measurements from sediment samples taken from the MSA layers at Wonderwerk Cave (240-150 ka) and Kathu Pan 6 (156-74 ka, minimum age). The results are compared to other proxy records from these sites and to modern transects of leaf wax n-alkanes in South Africa to assess the preservation and strengths of the method both in cave and open air sites. Our results show evidence for phases of increased humidity and shifting concentrations of C_3 and C_4 plants at both sites. Through the integration of environmental proxy studies and archaeological analyses from these sites and other newly published early MSA records in the area we can build a regional picture of palaeoenvironmental change during the earlier phases of the MSA in the arid interior.

Isotopic Evidence for Human Microhabitat Use Within and Across an Ecological Refugium, Panga ya Saidi, Kenya

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The Panga ya Saidi (PYS) cave site of coastal Kenya has been instrumental for understanding long-term human occupation and resource procurement in a climate resilient tropical deciduous forest within a larger wooded and grassland biome. The site is best known for containing the earliest known human burial in Africa, the oldest stratified evidence of marine engagement in eastern Africa, and an ~80-thousand-year sequence of technological innovations and material culture traits that encompass the MSA-LSA-Iron Age transitions. Because PYS as possibly a Late Pleistocene environmental refugia buffered against dramatic climate shifts and exhibits the earliest known appearance of the LSA in Africa, it presents a unique opportunity to test hypotheses centered on the adaptability of hominins across spatially and temporally variable plant landscapes.

We compare a new □62-thousand-year vegetation and precipitation record obtained from molecular $\delta^{13}C$ and δD of plant wax *n*-alkanoic acids extracted directly from PYS archaeological sediments to existing bulk carbon and oxygen faunal isotope data to highlight human resource acquisition strategies across plant-landscape microhabitat variability. Overall, the $\delta^{13}C$ data from the C_{28}-C_{32} *n*-alkanoic acids indicate a C_3 dominated environment over the past ~62 ka, while δD values suggest an increase in precipitation over time, with a relatively drier Late MIS 4 and Early-to-Mid MIS 3 compared to the LGM, Terminal Pleistocene, and Holocene. Interestingly, separating these two phases was a comparatively intense, yet short-lived, dry period to which the plant landscape, and $\delta^{13}C$ values, did not respond. Our data also suggests differences between the immediate PYS forest environment and those within the human hunting range, as indicated by the bulk faunal isotope data. The reliable coastal PYS forest would therefore have been particularly alluring to Pleistocene human populations during periods of climatic stress or resource instability, specifically as it was able to withstand relatively extreme, at least short-term, climate anomalies.

Abrupt change and feedbacks of precipitation, vegetation, and fire in the Turkana Basin during the early Acheulean

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Abrupt changes in environment have significant impacts on the humans living in and depending on the landscape. The amplitude and rate of climate changes have been shown to affect evolutionary changes in hominins, including the development of stone tool technology. However, it has been historically difficult to reconstruct past climate and ecosystem change at timescales that can resolve these transitions, which is crucial for testing hypotheses on the nature of this relationship. Further, the interplay between various ecosystem parameters, namely precipitation, vegetation, and fire, may have nonlinear interactions that are important for our understanding of evolutionary responses. Here, we present new ultra-high-resolution leaf wax hydrogen and carbon isotope and fire (PAH) biomarker data from the HSPDP WTK13 sediment core in the Turkana Basin, Kenya, a region containing multiple Acheulean sites known for their multi-purpose handaxes. Our West Turkana record spans a single high-amplitude insolation cycle (~21 kyr) just after 1.76 Ma, which accords well with the timing of the earliest evidence for Acheulean technology found in the nearby Kokiselei assemblage. We find that while precipitation responds with a simple nonlinear response to the relatively gradual orbital forcing, changes in vegetation and fire are more complex. On millennial timescales, there is coherency between ecosystem parameters, but the overall structures differ, indicating the prominence of feedbacks within the system. Multiple abrupt, oscillatory transitions occur in vegetation structure, which likely had a large effect on humans by exerting selection pressures favoring greater behavioral plasticity. It is possible that these patterns were exacerbated by the high-amplitude, orbital scale changes occurring during this time period. With higher-resolution, multi-proxy data, we are better able to focus on climate feedbacks and their impact on our hominin ancestors.

A biomarker and stable isotope approach to detecting climate-mediated site occupation patterns – a proof-of-concept study from La Ferrassie, France

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Human responses to climatic shifts are central to understanding key developments throughout our evolutionary history, including the disappearance of Neanderthals ~40 ka ago. Indeed, the archaeological record of late Neandertals shows a substantial amount of variability that has been discussed in the context of shifting climates. Yet, establishing links between these climatic and archaeological changes remains challenging due to a lack of climatic data that can be sufficiently related to archaeological evidence of human activities. Generating climatic data directly at archaeological sites is therefore key.

Diverse sample types from archaeological sites, from sediments to faunal remains, generate distinct types of climatic insights, offering different time resolution and varying relationships to past human activity. Here, we purposefully exploit such differences in an approach employing the stable isotope analysis of both 1) n-alkanes from sediment samples and 2) faunal tooth enamel from the Late Pleistocene Neanderthal occupations (MIS 5 – 3) of La Ferrassie, southwest France. In a previous study we documented a divergence between warm-climate faunal stable isotope signatures and sedimentary markers of freeze-thaw processes within a single layer of La Ferrassie. Here we explore this further by providing highly resolved climatic data from n-alkane biomarkers which are then compared to the faunal isotope data. The sequence of n-alkane ('leaf wax') δ^{13}C and δ^{2}H measurements we generate permit the inference of climatic conditions during the sedimentary formation of the site deposits – that is, a site-specific and naturally accumulated archive. We then contrast this with δ^{18}O and δ^{13}C data generated from tooth enamel and bone collagen of large bovids that represent the remains of Neanderthal hunting activity – an anthropogenically accumulated archive with a direct connection to Neanderthal occupations of the site.

Using this comparison, we demonstrate how deviations between natural accumulations and anthropogenically-related climate archives can be used to explore the different time scales and climatic conditions of sedimentary deposit formation versus the specific climatic conditions surrounding human activity at a site. Finally, we explore if this approach could be used to highlight climate-mediated site-occupation patterns, characterize conditions during occupation hiatus and thus explore potential climatic preferences of Pleistocene humans.

Session 47: The geological record of capable faults

Tectonic Geomorphology and Characteristics of the West Ilocos Fault System (Philippine Fault Zone) in the Eastern Solsona Basin, Philippines

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The Philippine Fault Zone (PFZ) is a 1200-km-long tectonic feature that transects the entire Philippine archipelago from northwestern Luzon to southeastern Mindanao. The PFZ consists of predominantly left-lateral strike-slip faults that have generated strong to major earthquakes in recent years, notably the Mw7.7 1990 Luzon Earthquake, and more recently, the Mw7.0 2022 Northwestern Luzon Earthquake. In northwestern Luzon, a network of strike-slip, reverse, and normal fault segments associated with the PFZ comprises the West Ilocos Fault System (WIFS). In this study, strands of the WIFS east of the Solsona Basin in Ilocos Norte were examined through geomorphological analysis, ground penetrating radar (GPR) surveys, and paleoseismic trenching. Morphotectonic features such as offset streams, truncated spurs, and subtle elevation changes were interpreted from anaglyph images and high-resolution digital topography data. In the municipality of Marcos, geomorphic markers indicate a general sinistral movement of the fault, with the fault scarp trending N20-35°E and dipping northwest. Ground penetrating radar surveys conducted along and across the fault scarp reveal discontinuous reflectors, corresponding to minor faults at a depth of about 5 m. A paleoseismic trench was then dug across the fault scarp, revealing the main fault, its splays, and displaced stratigraphic units. At least ten (10) stratigraphic units were delineated and described based on color, thickness, and sedimentological characteristics (e.g., texture, sorting, composition). Stratigraphic units are generally composed of muddy to silty sand and sandy gravels with angular to sub-rounded clasts of volcanic rocks sourced from the Ilocos Foothills (i.e., Bojeador Formation). Initial interpretation of the trench wall stratigraphy reveals at least two (2) faulting events that show normal displacement of stratigraphic horizons. These displaced horizons within alluvial deposits further imply recent movement along this segment of the WIFS, which we refer to as the East Solsona Basin Fault. The timing and recurrence of these faulting events have yet to be established through radiocarbon dating of charcoal samples collected from the stratigraphic horizons.

Paleoseismological studies along the Eastern Southalpine front revealing evidence of recent tectonic activity: implication for the seismic hazard assessment of NE-Italy

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The numerous paleoseismological investigation conducted in north-eastern Italy during the last 10 years allowed us to characterize the active front of the Eastern Southalpine Chain (ESC): a polyphase S-SE verging fold and thrust belt confined to the West by the sinistral Schio-Vicenza Fault System and to the East by the dextral strike-slip fault systems of western Slovenia and eastern Friuli. The main development of the ESC is associated to the messinian-pliocenic compressive event, which affected the inherited Dinaric structural architecture. Since Pliocene-Quaternary times the study area is subjected to a N-S compression and deformation is presently accommodated with velocities of the order of 2-3 mm/yr. The distribution of seismicity matches the arcuate shape of the Eastern Southalpine front, which is characterized by NE-SW to WNW-ESE and NW-SE trending structural features. Particularly, the strongest earthquakes (Mw ≥ 5.5) which affected the Veneto-Friuli region are located along the Venetian, Carnic and Julian prealpine border (1511 Mw 6.3; 1695 Mw 6.4; 1776 Mw 5.8; 1794 Mw 6.0; 1836 Mw 5.5; 1873 Mw 6.3; 1936 Mw 6.0 and 1976 Mw 6.5). Despite this, the active external thrust systems of the ESC are generally considered blind and the record of coseismic effects associated to seismic events are scarce. In this work we present a collection of 4 paleoseismological case studies, located all along the arcuate prealpine border, investigating the Bassano-Valdobbiadene, Meduno, Susans-Tricesimo and Colle Villano-Borgo Faris-Cividale Fault Systems. Our investigation documented many coseismic effects, both primary and secondary, mainly dealing with vertical displacement along shear planes, extrados secondary fractures and paleoliquefaction features, highlighting the recent tectonic activity of the investigated thrust faults. Particularly, the results we collected demonstrated that the frontal thrust systems of the Eastern Southern Alps, responsible of Mw ≥ 5.5 seismicity, are capable to generate permanent surficial deformation effects in occurrence of their activation.

The Kachchh Mainland Fault's Late Quaternary-Holocene Earthquake History: Evidence from Optically Stimulated Luminescence (OSL) Dating and Paleoseismology

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The Kachchh region has had at least four destructive moderate-to-large earthquakes in the past 500 years. With the exception of the Allah Bund earthquake in 1819, none of these earthquakes were, however, accompanied by surface rupture. Even the recent Mw7.6 Bhuj earthquake in 2001 took place on a blind fault with a sizable deformation zone that was reflected in the form of lateral spreads and had significant liquefaction and hydrological consequences. Previous research revealed that a number of faults in the Kachchh, including the Island Belt Fault, the Kachchh Mainland Fault (KMF), and the Katrol Hill Fault, were active during the Late Quaternary. But there is little supportive evidence available in the form of qualitatively reported recent Quaternary-Holocene rupture events and the nature of the active fault (Morino et al., 2007; Morino et al., 2008a, 2008b; Malik et al., 2008). As a result, nothing is known about the regional paleoearthquake events. This makes it more difficult for us to comprehend the tectonics of the area and the seismic risk. To address this issue, we investigated the fault exposures associated with the Kachchh Mainland Fault (KMF) near the Jhura dome using geomorphological data, near-surface geophysical surveys, and paleoseismological trenching. The tectono-geomorphic landmarks close to the dome, such as strath terraces, cut-fill terraces, alluvial fan surfaces, and north-facing fault scarps, were also thoroughly studied. We discovered deformation features that might have been brought on by multiple earthquakes between 9.7 and 6.4 ka in a paleoseismological trench that crossed the fault track. When compared to the archeoseismic and climatic records, the chronological order of the geomorphic markers also suggests a few recent event occurrences between 4.1-0.9 Ka. Given the interval between recurrences of 1000–1500 years, it is not unlikely that an earthquake of a moderate to large magnitude may strike KMF.

Re-characterizing a capable fault in Alaska, USA; How lidar and trenching data forced a reinterpretation of the Ragged Mountain fault

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The 33 km-long Ragged Mountain fault (RMF) forms the northwestern corner of the Yakutat microplate, which is colliding with the North American plate in south coastal Alaska at □5.5 cm/yr. The most prominent evidence of postglacial faulting is a zone of nearly-continuous antislope scarps cutting the colluvial-alluvial apron at the range front, documented by USGS in 1976. These extensional scarps were interpreted as 180 m of normal fault slip on a shallow (13 degrees) west-dipping former reverse fault (fault inversion). If true, this would make the RMF the fastest-slipping normal fault in the world (15 mm/yr). However, the microplate is in a highly compressional setting; how could the world's fastest extensional fault exist there? In 2005-06 we remapped the central part of the RMF from lidar DEMs and excavated five trenches. New observations: (1) downslope from the antislope scarps lay a subtle, semi-continuous reverse fault scarp, not recognized in 1976, and (2) strata in the footwall had been folded to near-vertical and contained multiple, parallel, postglacial flexural-slip faults. A trench across the antislope scarp exposed evidence for three displacements: at 0.5–3.9 ka; slightly younger than 8.3 ka; and at 18.1–21.8 ka (recurrence intervals 4.4–8 kyr and 9.8–13.3 kyr), with displacements per event ranging from 15 to 40 cm. In the thrust trench ruptures were dated at 2.8–5.9 ka; 5.9–17.2 ka, and 17.2–44.9 ka (mean recurrence intervals 7.2 kyr and 19.5 kyr). Displacements per event ranged from 26 to 77 cm. We interpret the thrust fault as the primary seismogenic structure, and the antislope normal faults as secondary collapse structures in the fault tip. The largest reverse trench displacement (77 cm) equates to average displacement expected for a 33 km-long reverse rupture, and a slip rate of > 0.08 mm/yr. Our revised characterization was based on the suite of surface-rupture features observed in several post-1976 reverse surface ruptures, especially the 1980 M7.1 El Asnam, Algeria, earthquake, which occurred four years after the USGS characterization. When assembling databases of surface rupture, compilers should be aware of possible defects in interpretation in these older reconnaissance studies.

Fault Parametrization for Probabilistic Fault Displacement Hazard Analysis. Case Study from the Upper Tiber Valley

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Fault displacement can be particularly risky for critical infrastructure located in the nearby of a capable fault. Usually, this issue is dealt with zonation and avoidance strategies, but sometimes this option is not feasible for existing facilities. Probabilistic Fault Displacement Hazard Analysis can address this problem, assessing the likelihood of exceeding a certain level of displacement at the site of the infrastructure. Since the early 2000s, several authors proposed different methodologies for different kinematic contexts. Using databases of coseismic ruptures of past earthquakes, empirical regressions have been proposed to assess the probability of occurrence and the probability of exceedance of certain values of displacement, for both Primary and Distributed faulting.

The probability of exceeding a certain value of displacement at the site of interest is also related to the probability of occurrence of a surface faulting earthquake on a certain fault. To perform the PFDHA, the fault parameters and earthquake rates are needed.

We propose the results of PFDHA applied to the Anghiari Fault, a poorly constrained normal fault located in the Upper Tiber Valley (Italy), and the methodological approach used to gain the fault parameters needed to perform the PFDHA.

The Anghiari fault is an 11 km-long, NE-dipping, highly segmented normal fault bounding the western side of the Sansepolcro basin. It is one of the synthetic splays of the Altotiberina low-angle normal fault system.

We started with geological survey, morphotectonic analysis and geophysical investigations to accurately map all the fault segments and to select sites suitable for paleoseismologic trenching. To assess the capability of the fault and its rate of activity we carried out a paleoseimic campaign, investigating several segments of the Anghiari fault. To obtain a multiscale evaluation of the fault slip rate, we collected samples to date paleosurfaces displaced by the fault with the cosmogenic nuclides methodology.

At the end we performed the PFDHA obtaining curves and maps of hazard for both primary and distributed faulting.

The San Ramón thrust fault and the sustainability of Santiago, Chile: Increasing seismic risk and recommendations for public policy

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The San Ramón thrust fault system is located at the west foot of the main Andes Cordillera, along the piedmont of a more than 2000 m high mountain front that limits the central valley where Santiago, capital city of Chile, inhabited by more than 7 millions of persons, is located. Paleoseismological and seismological results evidence that this is an active fault capable to produce large earthquakes with superficial rupture. Its potential activation constitutes a challenge for the city of Santiago as well as for the entire metropolitan region. The eastern border of the city has experienced an accelerated urbanization in the last four decades with respect to the previous four centuries, with increasing seismic risk. This is a risk element not yet included in Chilean public policies, whose consideration is essential regarding the sustainability of the city, since a growing population of people lives directly on its trace as well as in its surroundings.

We conclude with seven recommendations for public policy: (1) to define the San Ramón Fault as an active fault; (2) to restrict the foundation of any infrastructure in a 300 m wide fringe along the San Ramón Fault trace, with the possibility of carrying out studies to specify the location of this fringe at surface, including it as a constitutive element of local and regional urban planning policies; (3) to modify the Chilean Seismic Code to incorporate active faults; (4) to carry out hazard studies related to landslides susceptibility, given the potential activation of the San Ramón Fault and incorporating these areas into regional and urban planning instruments; (5) to make available accurate and pertinent information to the public regarding the location and seismic risk of the San Ramón Fault; (6) to define the restriction fringe along the San Ramón Fault trace (300 m), as an area of environmental protection and natural conservation along the Andean piedmont; and (7) to define and to implement a governance strategy for the design, implementation, monitoring and evaluation of sustainable urban planning, in coherency with the Sustainable Development Goals, and the national and global policy on Disaster Risk Reduction.

New Observations of the Surface Slip Distribution of the Ruptures to the 24th and 25th February 1981 Ms 6.7 and 6.4 Earthquakes, Pisia and Skinos Fault, Greece

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Earthquake surface ruptures are the surface expression of coseismic slip on a fault produced during large magnitude earthquakes. Extensive field observations of these ruptures can provide important insights into fault kinematics and relationships between regional tectonics, faulting processes and seismic hazard. However, only a few well-documented examples of normal faulting surface ruptures exist in the literature. The 1981 eastern Gulf of Corinth seismic sequence generated ruptures on the Pisia and Skinos Faults, however, only a few offsets were recorded immediately after the earthquakes, with measurements spacing hundreds to thousands of metres apart. The 41-year-old rupture is still well preserved along the Pisia and Skinos normal faults, both as bedrock fault plane lichen stripes and ruptures in colluvium. We re-visited sites close to those measured in 1981 and found offsets only slightly larger or smaller than those measured in 1981 (± < a few decimetres even for sites that had over a metre of slip in 1981). We found no clear evidence of an overall increase in slip due to post-seismic motion, so the 1981 slip distribution is relatively-well preserved. We mapped the ruptures, taking measurements at 223 sites spaced tens of metres apart or less along strike, and have produced detailed surface slip distributions, recording strike, dip, plunge, plunge direction, slip, heave and throw. Kinematics obtained along the two faults display asymmetric bell-like slip distributions that, when summed across strike between the two faults, reveal a double-humped, symmetric slip distribution. The two maxima in slip on the summed profile occur at two along-strike bends in the ruptures where strike and dip values on the fault planes vary. The bend for the Pisia example is also associated with an abrupt change in the slip-vector azimuth despite the lateral continuity of the rupture. These kinematic observations provide insights into possible geometric barriers to rupture propagation and how these relate to surface slip distributions and fault scaling relationships. Detailed measurements like those herein are key to understanding faulting processes and fault-slip hazard on capable faults, which has important implications for seismic hazard.

Updated regressions on the likelihood of surface faulting

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Several factors define if an earthquake will rupture all the way to the topographic surface, including moment magnitude, earthquake kinematics, local lithological characteristics. Surface rupture starts to occur for earthquakes of Mw 5 (or even lower in peculiar context like volcano-tectonic settings) and becomes more and more likely for higher magnitudes.

The likelihood of primary surface faulting as a function of magnitude is the first branch in the logic trees currently adopted for fault displacement hazard assessment and thus has a paramount role, especially for probabilistic evaluations. Nevertheless, the scaling equations currently adopted were developed several years ago; we attempt to update such relations by exploiting more recent earthquakes. We selected from the ISC-GEM seismic catalogues the earthquakes with Mw higher than 5.5 occurred between 1992 and 2018 and with epicenter located onshore and hypocentral depth lower than 20 km. We build a homogeneous dataset categorizing the events as having or not having ruptured the surface (88 and 276 events, respectively).

Then, we compute empirical regressions of the likelihood of primary surface faulting as a function of magnitude on the entire dataset and on subsets for the different earthquake kinematics. Overall, we found a general agreement with existing equations, except for reverse earthquakes; we discuss possible causes related to the dataset or adopted methods. We argue that the documentation of surface faulting gained an increased attention in the last years, given the critical role posed by fault displacement hazard for high-risk plants. New techniques that are nowadays routinely adopted (e.g., InSAR, optical image correlation) allow to investigate in an unbiased manner the entire earthquake population, thus providing sound results. The methodological choices in the first stages of dataset implementation (e.g., depth threshold) may affect the final result; in this sense, we define clear thresholds, to assure repeatability of the procedure.

The equations derived in this study can be used together with existing equations, handled in a logic tree structure; similar equations can be derived for different seismotectonic settings or geographic regions, whenever a sufficient earthquake dataset is available.

Session 48: Quaternary climate, landscape and surface processes in mountain belts

Geomorphic settings of wetlands on quaternary volcanoes in the humid tectonic zone: Recharge water characteristics and responsiveness to climate change

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In northeastern Japan (Tohoku region), numerous wetlands are on a backbone range (Ou Mountains), and northwestern winter monsoons bring in a large amount of snow. In this study, we comprehensively examined the landforms, climate, and hydrological settings of wetlands on the volcanic surface of the Ou Mountains. Additionally, we clarified that the responsiveness to climate change differs depending on the local geomorphic and hydrologic conditions.

Wetlands of various geomorphological origins are formed in the study area. The tectonic lineaments due to east-west compression and the gravitational deformation, including landslides and linear depressions, are representative sites of wetlands. On the original volcanic surfaces of high-elevation areas, the tectonic lineament and linear depressions are covered with snow drift. Furthermore, wetlands are formed on the saddles with less snow accumulation.

We observed soil temperature, moisture, and electrical conductivity in three peatlands along a tectonic lineament and on the saddles from 2018 to 2019. The peatlands were formed during Holocene warming and humidification. In the lineament, the annual change in electrical conductivity was small. The soil remained moist for approximately 1.5 months after the snow has melted completely and then changed according to the season—dry or wet. In the saddles, the electrical conductivity fluctuated wildly, increasing during the snow-covered periods and decreasing after the snowmelt season. In addition, the soil moisture content also fluctuated wildly with precipitation. Groundwater generally has higher electrical conductivity than precipitation. Therefore, the peatland along the tectonic lineament is mainly recharged from snowmelt runoff. Precipitation and shallow groundwater from the surrounding slopes contribute to recharging in the peatlands on the saddles.

With the long-term warming trend in the Tohoku region, a reduction in snow accumulation and melting of snow at an earlier stage will significantly impact wetland environments. Using aerial photographs taken in 1976 and 1998, we measured the area for each wetland type and found that snow-fed type areas have shrunk, while those on saddles have increased. Therefore, it was revealed that the responsiveness to climate warming depends on the characteristics of the recharge sources that reflect the landform.

Evolution of the polygenetic Frébouge Cone during the Holocene (Val Ferret, Mont Blanc Massif)

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Proglacial settings in the Alps are typically polygenetic, often characterised by a complex and discontinuous interplay between glacial, fluvial, and gravitational processes. These processes yield high volume of sediments, which usually exceeds the transportation capacity. The overshoot proglacial sediment load leads to accumulation on slopes, and thus, to failures such as rock avalanches or debris flows. Such failures can occur unexpectedly and harm the villages and infrastructure in the vicinity of proglacial environments. The northern slopes of the Ferret and Veny valleys in the Mont Blanc Massif are home to several polygenetic cones and portray a stunning field laboratory for the exploration of the interplay between the glacial, fluvial, and gravitational processes. This study investigates one of the active and well-preserved polygenetic cones in these valleys, namely the polygenetic Frébouge Cone, in order to disentangle the geomorphic processes that contributed to its formation, and to reconstruct its evolution. To achieve these goals, detailed field and remote mapping, ^{10}Be surface exposure dating of different geomorphic features, and runout modelling with DAN3D® were applied. The geomorphological map revealed complex interactions of glacial, fluvial, debris flow, and rock and snow avalanche processes. The established chronology indicates two major fluxes of debris flows, the first one at ca. 2 ka, and the second at ca. 1 ka. In addition, a rock mass with a maximum volume of to 12 Mm^3 collapsed in the upper reaches of the cone at ca. 1.2 ka and overran the cone by travelling more than 100 m up onto the opposite valley slope. Afterwards, the Frébouge glacier overrode the cone several times leaving moraines and striated boulders, reaching its maximum extent ca. 300 years ago. This study underscores the untwisting of complex interaction of surface processes in the Alpine valleys, which are prone to hit the urban areas and infrastructure.

Late-Quaternary Glacial History of the Milang Sub-basin, Lahaul Himalaya, Western Himalayas

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Glacial and Geological studies investigate the pieces of evidence to understand the timing and extent of glaciation of the late Quaternary period. Studying past glacial records can also be helpful to reconstruct the effects of environmental change in the region. The study of the Quaternary glaciation in the Himalayan and Tibetan regions has remained the focal point of several scientific research. The palaeo-glacial and palaeo-climatic reconstruction of the Milang watershed (MLW) has been done with the help of using geomorphic mapping and cosmogenic 10Be surface exposure, and Optically Stimulated Luminescence (OSL) dating. The MLW is a sub-basin of the Chenab basin in the Lahaul region of the Western Himalayas. It lies in the zone of transition between the arid regions of Spiti, Ladakh, and Tibet and the monsoon-influenced regions south of the Pir Panjal in Himachal Pradesh. This study reports the first 10Be dates for the MLW watershed and tries to co-relate the results with a regional framework for palaeo-glaciation in the Lahaul Himalaya as given. Based on the Landform Mapping, ^{10}Be exposure and OSL ages the palaeo-glacial extent of the MLW has been reconstructed. Three major palaeo-glacial stages, namely, Chandra (~81.5 ±3.94 ka), Darcha (12 ka to 15.5 ka) and Mulika (~8 ±1.47 ka) have been identified. The Chandra stage of glaciation refers to a massive valley glaciation influenced by the Monsoon. The glaciers occupied the Chandra and Bhaga valleys. The Darcha stage represents a valley-wide glacier extended in the main Milang valley. It coincides with the regional glacial stages of SWHTS (Semi-arid Western Himalayan-Tibetan Stage) 2A, SWHTS 2B, and SWHTS 2C influenced by Westerlies. The Mulkila stage was a major glacial advance stage that occurred during the early Holocene. It is represented by well-preserved glacial trimlines and sharp-crested moraine ridges. During this stage the South Asian Monsoon moisture was dominant and glaciers were more sensitive to precipitation.

Multiple glacier river-blocking events on the southeastern Tibetan Plateau in response to climate changes since the last glacial maximum

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The detailed evolution of valley-damming by glaciers on the southeastern Tibetan
Plateau, including the very large Gega dammed lake, is reconstructed based on observed sediment sequences, and optically stimulated luminescence (OSL) dating. In total, six main lithofacies associations are inferred that represent three relevant sedimentary environments associated with the dammed lakes, i.e. lacustrine, deltaic and fluvial. Since the local last glacial maximum (LGM), there have been at least three river-blocking events and consequent phases of lacustrine development in the Gega and Jiedexiu dammed lakes. They occurred at ca. 25–17 ka, 14–11 ka, and ~4 ka. Sedimentological evidence shows that the glacier-dammed lakes were not stable; they experienced oscillations of lake level through short-time drainage events. The damming events and subsequent
outburst floods were likely triggered by changes in the extent and thickness of glaciers, caused by rapid climatic changes.

“Morphotectonic evolution of the Albanian Dinarides belt from preliminary meteoric 10Be/9Be denudation rates”

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The Albanian Dinarides correspond to the central part of the Dinarides – Hellenides orogen, a SW-vergent fold-and-thrust belt resulting from the convergence and the collision between the Adriatic and European plates. Prominent topographic differences reflect the geologic organisation of the belt into NW-SE-oriented structural domains, which can be summarised into an external compressional zone, and the extensional continental interior, characterised by graben basins.

Modern seismicity (e.g. 1979, Mw 7.1 Montenegro, and 2019, Mw 6.4 Durres earthquakes) together with geomorphic features such as marine and river terraces, endorheic basins, wind gaps, hanging valleys, suggest that this region has been tectonically active since at least late Quaternary. Despite this evidence, a thorough understanding of the morphotectonic evolution of the area is still limited. Since deformation style and rock erodibility are the primary factors controlling the evolution of the topography, we aim at reconstructing the Quaternary morphotectonic evolution of the Albanian fold-and-thrust belt by using geomorphic markers. We first focused our attention on drainage network analysis: rivers are able to respond quickly to tectonic and climatic changes, becoming good candidates to investigate how the landscape reacts to external forces, and how tectonics, climate, and surface processes are related. Here, river denudation rates will be used to quantify Quaternary erosion rates, which will in turn serve as proxies for uplift rates. We calculate river denudation rates by employing the innovative technique of meteoric 10Be. Unlike the well-known in situ Be technique that can be exclusively employed in quartz-rich lithologies, with this new technique also quartz-poor lithologies can be processed; this is particularly useful in Albania, where carbonate rocks and ophiolites predominate.

After morphometric analysis and remote mapping of all the major drainage basins of Albania and western Macedonia, twenty basins were chosen for sampling. These basins are in equilibrium, develop on a unique lithology, lie in the proximity of the main tectonic structures, are spatially distributed to cover all the main tectonic domains. We expect variable uplift rates over different sections of the belt, reflecting different tectonic activity across the NW-SE-oriented structural domains, and evidences of the contribution of deep processes to landscape evolution.

Session 52: Eurasia, one continent one common past: cross-continental stratigraphical correlations

A potential second stage for the Middle Pleistocene Subseries based on the Mid-Brunhes event

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The Global boundary Stratotype Section and Point (GSSP) at Chiba, Japan defines the base of the Middle Pleistocene Subseries and Chibanian Stage with an astronomical age of 774.1 ka. This boundary represents the approximate midpoint of the Early–Middle Pleistocene transition, a 1.4–0.4 ka interval marked by a progressive increase in the amplitude and asymmetry of climate oscillations and a shift towards quasi-100 ky periodicity. Both units currently extend upwards to the base of the Upper Pleistocene Subseries dated provisionally at ~129 ka. The Middle Pleistocene with a 645 kyr duration is the second longest subseries of the Quaternary. Introducing a second stage, beginning at the approximate mid-point of this subseries, would provide a useful division. The 'Mid-Brunhes Event' (MBE) more recently termed the 'mid-Brunhes Transition' is an abrupt step-change to increased amplitude of the quasi-100 kyr cycles and to warmer interglacials from MIS 11 onwards, as revealed by Antarctic ice core records, the LR04 benthic foraminiferal isotope stack, and a recent long alkenone paleotemperature record from the central Mediterranean Sea. Other long-term changes at this time include an abrupt weakening of the East Asian Summer Monsoon, suggesting an increase in average Northern Hemisphere ice volume. The base of this new stage would reasonably be placed at around the MIS 12–MIS 11 transition (Termination V, ~420 ka), an interval of rapid change clearly recognised in the marine record. This level appears to approximate the bases of the Holsteinian, Hoxnian, Likhvinian, and Zavadivian regional stages across northwestern and central Europe, the Russian Plain, and the Ukrainian Loess Plain; and can be traced across the Chinese Loess Plateau. Climatostratigraphic signals associated with Termination V (~420 ka) would serve as the primary guide to this proposed new stage for the Middle Pleistocene. The 'Bermuda' geomagnetic excursion occurring within a prominent relative paleointensity minimum at ~412 ka in MIS 11 offers additional stratigraphic characterization. Such a second stage would terminate the Chibanian, eliminating its redundancy as the sole stage of the Middle Pleistocene.

The stratigraphic subdivision of the Late Pleistocene in the Northeastern European margin

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We present new results obtained on the eastern White Sea coast in the Kuloi Plateau area (Northeastern Europe). Lithostratigraphic studies of sedimentological successions, OSL dating, foraminifera and malacofaunistic analyses, as well as correlation of available continental and marine palaeoarchives were carried out to reconstruct the chrono- and event stratigraphic sketch reflecting the relationship of glaciations and marine transgressions in the region. A composite sequence of the Upper Pleistocene lithological units linked to the Late Pleistocene sedimentation environments in the southeastern White Sea region was resulted.

In the southeastern White Sea coast, Upper Pleistocene composite sequence includes Mikulino, Chermen, Kalinin, Leningrad and Ostashkov Groups (Horizons in Russian lithostratigraphy). Mikulino Group is composed of silty clay with rounded clasts, shells and benthic foraminifera, overlain with sub-supralittoral sandy sediments, OSL-dated to 138-103 ka. They correlate with Eemian Stage (MIS 5e) and Boreal glacioeustatic transgression which was succeeded by eustatic less active Belomorian one. The sediments of Belomorian transgression ESR- and OSL-dated at 92-77 ka and correlated with Early Weichselian Stage (MIS 5d-a) and Chermen Group are composed of silty sediments with shells and thin-layered sandy deposits. This transgression could be triggered by changes of relative sea level due to the Early Weichselian cool-warm rhythms and evolution of the early Late Pleistocene glaciations centered in the Barents-Kara region. Kalinin Group is composed of solid silty clay without any paleontological remnants overlain by the sub-supralittoral sandy deposits with shells and shell detritus, and gravel beds. They have been ESR- and OSL-dated to 77-52 ka (MIS 4-3); both clay and sandy-gravel beds were accumulated during the Mezen marine transgression, which took place in the Middle Weichselian. Corresponding marine deposits were earlier described only in the eastern part of the region (Jensen et al., 2006). Ostashkov Group is composed of till, glaciofluvial and glaciolacustrine deposits correlated to LGM and initial deglaciation of the Late Weichselian Stage. Our data evidence that marine environments prevailed on eastern White Sea coast throughout the Late Pleistocene, with the exception of MIS 2.

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Obliquity-driven magnetic susceptibility cycles in a long-term Quaternary fluvial fan in the Pannonian Basin - and their prospects in terrestrial stratigraphic correlations

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Fluvial fans are controlled by variations of physical processes in the catchment and of distributive avulsion dynamics, thus can give complex response to climate changes. The Maros Fan is a long-term, Late Miocene–Quaternary fluvial fan accommodated by the continuous subsidence of the Békés Basin. A high-resolution stratigraphic investigation of the Quaternary Maros Fan is performed based on wireline log correlations, completed by measured and logged magnetic susceptibility (SUS) records. The interpretation is supported by analyses of the magnetic granulometry based on frequency dependent SUS measurements, and on magnetic mineralogy based on scanning electron microscope and hysteresis investigations.

The time-series analyses of the Maros Fan SUS records reveal the reliable occurrence of the ~41 ka frequency, together with the customary ~100 ka cycles. Towards the source-distal sections the intensity of the ~41 ka cycles decreases, while that of the ~100 ka cycles remains strong. In spite of the apparent stratigraphic and spectral similarities of fluvial fan and loess SUS records, the magnetic phase of the Maros Fan sections is expressly related to the detrital magnetite that originates from the catchment during early postglacial permafrost degradations; the latter following climatic amelioration into interglacial events.

The recording of the ~41 ka cycles cannot be attributed to the high sedimentation rate, since it is similar in the Körös Basin and Makó Trough; however the cycles cannot be detected in these source-distal fluvial settings. It is a particular stratigraphic feature of source-proximal fluvial settings, i.e. the climate controlled rearrangements of the distributive drainage on the fluvial fans, in concert with the climate-controlled occurrence of the permafrost-related magnetite fraction, derived from the catchment, which is responsible for the excellent amplification and preservation of the ~41 ka SUS variations.

As a local phenomenon, this is significant since it records the obliquity-driven variations of permafrost development in the Carpathians. However, fluvial and alluvial fans are recent widespread depositional landforms within the Eurasian Mountains and were possibly the same during the repeated Quaternary deglaciations. Thus, obliquity-driven SUS variations of source-proximal fluvial settings, attached or adjacent to regions of loess deposition should also be assumed when explaining Quaternary SUS records.

Proposal for the lower boundary of the late Middle Pleistocene stage in Central Europe

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The late Mid-Pleistocene is roughly correlated in the European Quaternary with stratigraphical units from the Holsteinian Interglacial to the Saalian Glaciation that is with the marine isotope stages from 11 to 6. A stratigraphy of this part of the Quaternary in Europe is far from being clarified, regarding the interaction between the environmental processes and climate. Stratigraphical subdivisions of the northern, glaciated part of the continent contain hiatuses or units with incredible setting and it makes interregional correlation difficult. On the other hand, stratigraphical schemes of the extraglacial area, based on sites with fluvial, lake and loess sequences, are much more convincing and complete. Combining the schemes from these two regions still remains a challenging field in the European stratigraphy. Among the main limitations, there is a lack of good dating methods that could be applied to deposits of this part of the Mid-Pleistocene whereas correlation of the terrestrial sequences with high-resolution oxygen isotope deep-sea curves can solve only partly the dating problems. Starting from the bottom of late Mid-Pleistocene, a deglacial part of the Elsterian Glaciation is represented by widespread glaciolacustrine sediments deposited in vast proglacial lakes of the retreating ice sheet. These sediments were identified from the Netherlands and the Lower Elbe region in the west to Poland and eastern Belarus in the east. They pass upwards into the sediments, either of the Holsteinian sea in northern Germany and the Kaliningrad District of Russia or into fluvial deposits in other parts of this region. Location of the glaciolacustrine sediments and their draining towards the Holsteinian sea in the north played a principal role in establishing the modern fluvial pattern in the northern part of continental Europe. Thus, the lower boundary of the second Mid-Pleistocene stage in Central Europe could be set at the Elsterian/Saalian boundary, at the top of the late Elsterian glaciolacustrine series that forms a key horizon in a considerable part of northern continental Europe. It could be also indicated by the Chegan palaeomagnetic excursion. The research was done within the project no. 2017/27/B/ST10/00165, funded by the National Science Centre in Poland.

An update of the Late Pliocene and Early Pleistocene vegetation and climate stratigraphy of NW Europe

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Studies into the chronostratigraphy and climate record of the Late Pliocene and Early Pleistocene in northwest Europe was spurred by pioneering work of Waldo Zagwijn. This period of Earth history is particularly important because of the inception of ice sheets in the Northern Hemisphere. However, Zagwijn's classic stratigraphic framework based on palynology is difficult to correlate to the Marine Isotopic Stages (MIS) due to a lack of independent dating of the terrestrial deposits. The type area in the Dutch-German border region is characterized by a complex local stratigraphy and represents an incomplete sedimentary record.

We aim to reconstruct a new stratigraphic composite reference section for the Late Pliocene and Lower Pleistocene of the shallow marine to deltaic deposits of the western Netherlands and North Sea. We present a new 380-m deep borehole from Petten and an updated record from Hank to construct a composite record for the late Pliocene and early Pleistocene vegetation and climate changes. The shallow-marine to deltaic facies are logged in detail and yield well-preserved and diversified pollen and organic-walled dinoflagellate cyst associations. New onshore and offshore paleomagnetic data enable a refined correlation of the terrestrial pollen zones to the MIS. Sedimentological analyses from these boreholes reveal the local depositional environment and aid in identification of hiatuses in the record. Organic geochemical biomarker data provide a quantitative paleotemperature record. Combined, they show clear late Pliocene to earliest Pleistocene interglacial-glacial cyclicity, expressing variation in sediment supply, large-scale landscape reorganization and terrestrial temperature variation.

A spliced record is constructed and evaluated using the global glacioeustatic and paleoclimatic record. Comparison of the splice to the upland type area data provides new insights in the timing and duration of the classic regional terrestrial stages – Brunssumian, Reuverian and Tiglian – and highlights remaining gaps in the record. An integrated multiproxy framework for the Late Pliocene and Early Pleistocene of the Netherlands, in a scientific drilling framework, will lead to improved reconstructions of climate, sea-level and sediment provenance.

Eurasian peatlands as valuable deposits of the synchronous Anthropocene Signal

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Peatlands, spanning 3% of the Earth's surface, are crucial archives of stratigraphically defined "Great Acceleration" of human impact and are valuable deposits of the Anthropocene evidence. In our study, we would like to answer the question of what is the synchronous anthropogenic marker in selected Eurasian peatlands, which could allow for distinguishing new epochs. 50 cm-long peat cores were collected from the Sudetes in Poland, near Tomsk city (Russia), China, the NW part of Iceland, the western part of Estonia and Spitsbergen to identify trace elements, isotopic signature of Pb and 239 + 240Pu concentration in the peat (except for China, where Pu was not measured).

The maximum concentration of Pb (from 4 – 360 mg kg-1) is strongly distinct between investigated sites and, together with the first appearance of spheroidal aluminosilicates, differs with the deposition time. Comparison of industrially driven Pb deposition in archives from different countries indicates regional or local differences due to the individual history of industrial development. However, the rise in trace metal inputs for Pb in the 1950s does appear to be synchronous for all studied peat deposits. A pronounced peak in 239+240Pu level, which refers to 1952 and 1963, was established.

While individual peatlands differ with industrial Pb history, a substantial upturn of Pb concentration in the 1950s and a clear nuclear weapon test signal were determined in all the profiles, confirming the value of peatlands as archives of globally expanded human-driven changes of the Earth.

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Session 55: Understanding the human-animal-environment interface in Quaternary South Asia

Palaeolithic assemblages, raw materials, palaeoenvironments and landscape adaptations in the Lower Son Valley, Uttar Pradesh, India

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This study highlights recent explorations undertaken to investigate the palaeoanthropological potential of the Lower Son Valley. During these investigations, 61 new Palaeolithic and microlithic sites have been identified along with three vertebrate fossil sites in the valley. The valley preserves multi-technological (probably transitional) phases starting from Late Acheulean(?), Middle Palaeolithic, Upper Palaeolithic and microlithic. The Palaeolithic and microlithic artefacts were collected from seven different sites probably spanning from ~140 ka to 48 ka based on currently-known evidence (i.e., Patpara, Bamburi, and Dhaba etc). The valley's assemblages have the potential to shed light on global questions, such as the end of the Acheulean, and local debates, such as the position of the Indian Upper Palaeolithic. The raw material utilised in the valley is primarily porcellanite which is derived from exposures of the Semri Group of the Vindhayan Supergroup and is quite versatile and unique in nature which allowed Late Acheulean to microlithic populations to exploit it for artefact production. Other raw materials like chert, chalcedony, quartz, quartzite, limestone and agate are also utilised. The Quaternary sediments in the valley have also yielded mammalian fossil specimens such as long bone fragments, dental specimens and antler fragments. Late Acheulean to Upper Palaeolithic sites are generally located on the south side of the Son River, while microlithic sites are found throughout the study area. Furthermore, a ~11-meter-deep geological excavation was also conducted to reconstruct the regional Late Pleistocene palaeoenvironmental framework and date the associated sediments. Preliminary analysis indicates that the sampled sediments at that specific location date back to ~57 ka and grain size analysis shows an increase in coarser deposition after ~30 ka, probably indicating an increase in precipitation. Broadly, the valley has potential for more multi-proxy studies to understand hominin adaptations, technological transitions (Late Acheulean to microlithic) and palaeoenvironments in this north-central region of India.

Reconstructing the genetic ancestries of Neolithic and Megalithic Populations of Burzahom, Kashmir using Ancient DNA Analysis

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Burzahom is a unique archaeological site in Kashmir, India that demonstrates successive transitions from the Neolithic era, to the Megalithic era, to the early historic period in south Asia. There is evidence of cultural interactions between this site and neighboring regions such as Central Asia and the rest of South Asia. However, more than five decades after the excavation, questions on the genetic identities and genetic interactions of the people who resided in Burzahom remain unanswered. This study is an attempt to characterise the genetic ancestry of individuals from Burzahom through ancient DNA analysis. DNA was extracted from petrous bones and teeth of seven individuals from the site and sequenced on the Illumina HiSeq platform. Five out of the seven samples yielded authentic ancient DNA, as confirmed by DNA damage patterns using the software MapDamage. Of these five samples, two had sufficient data for downstream analyses including genetic sex assignment, which showed that both samples belong to male individuals. One of these samples was dated using Accelerator Mass Spectrometry to 2027-1778 BCE, while results from the other are awaited. These individuals were assigned to mitochondrial haplogroups M65a and U2b. Both these haplogroups are found in south Asia today. Haplogroup U2b has been found previously in an ancient individual from the Harappan site of Rakhigarhi, India. Autosomal data analyses for both samples will help us further understand the genetic ancestry and migratory history of residents as well as their genetic relationships to contemporary and later populations in South and Central Asia. This study represents one of the oldest ancient genomic datasets from South Asia thus far and is a milestone for ancient DNA analysis in the Indian as well as broader south Asian context.

Investigating the palaeoecological implications for hominin occupation in the Pinjore Formation (2.58-0.63 Ma), Siwalik Hills, northern India

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Role of environmental stimuli in human evolution, expansion, speciation, adaptation and extinction has been highlighted time and again by scholars. Global climate change from forest-dominated to grassland-dominated environment in the Plio-Pleistocene period has been identified as an important factor for hominin dispersal around the Old World. However, in light of recent researches this priori is being questioned and debated. The fossils of *Homo erectus*, one of the first known early human species to expand outside of Africa, has been discovered from Early Pleistocene deposits of East Europe, West Asia, and Southeast Asia, thereby placing Indian Subcontinent in general- and the Siwalik Hills in particular- as an important dispersal route. However, apart from the chronologically and taxonomically ambigous Hathnora cranium, no unequivocal fossil hominin remains have yet been reported from the region. Based on the presence of fauna often associated with *Homo erectus,* like *Theropithecus oswaldi, Hippopotamus,* and *Megantereon* in the Early-Middle Pleistocene deposits of the Siwalik Hills, scholars have predicted the presence of hominin remains in the region, yet none have been found. Currently, lithic artefacts are the only known signatures of hominin occupation in the region, primarily occurring as surface deposits without secure dates. The Pinjore Formation (2.58-0.63Ma), north of Chandigarh represents the most extensive and the only continuous Early-Middle Pleistocene deposit in the region with a rich record of fossilised vertebrate remains and recently, Ostrich eggshells. In light of absence of stratified lithic deposit and secure dates, palaeoecological and faunal analogies with other Early-Middle Pleistocene hominin bearing sites, can provide an adequate explanation for presence/ absence of hominins in the region.

Late Pleistocene Archaeological Records of Luni-Sukri Basin in the Thar Desert, Rajasthan,India

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South Asia is one of the major geographic regions to address research questions related to, Paleolithic archaeology and Quaternary environments, such as climate change, landform evolution, human occupation, adaptation, dispersal, and cultural transitions. Its northwestern parts encompass the continuation of mid-latitude deserts. Thar, or the Great Indian Desert, is spread over 5000 sq km from the Lower Indus valley to the Aravalli Hills range. Its dynamic palaeo-geographical setup acted as a barrier or corridor for the Paleolithic hominins. However, it represents rich lithic artifact assemblages from the Mid to Late Pleistocene geological context. Culturally, these findings from the Lower Paleolithic onwards until the Late Paleolithic provide key information on hominin occupation and regional technological development while highlighting other critical research problems. Our focused area is the Luni-Sukri river basin, a unique geographical area located on the southeastern edge of the Thar Desert.The present study addresses the hominin landscape adaptability of a select ecozone relating to the lithic cultural traditions. Over the past several decades, multidisciplinary research projects have revealed archaeological and geochronological records in the other Parts of the Thar Desert. We conducted primary field observations and pilot studies in the relatively unexplored region and came up with new insight related to earlier hominin presence here. We have adopted a multiproxy approach to evaluate the recent findings,including geo-archaeological explorations. The study investigates the Paleolithic sites' formation processes, spatial distribution patterns, and stratigraphic association.The lab methods include detailed lithic analysis to understand reduction sequences and petrographic analysis of identical rock types for raw material characterization. The lab methods include detailed lithic analysis to understand reduction sequences and petrographic analysis of identical rock types for raw material characterization. The use of selective cryptocrystalline raw material and technological aspects indicates the presence of advanced middle to late Paleolithic, emphasizing regional cultural diversity.The under-processing sample for dating will confirm the chronological frame of these sites.So this attempt will help to understand questions related to the Palaeolithic cultural sequence of the Thar Desert and subordinate areas of the western margin of the Aravalli range based on raw material variability and lithic strategies in different regions.

Out of the Glue: Unravelling fossil localities in the cemented bed of the Bearma, a lesser-known river valley in Madhya Pradesh, Central India

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Fossilised faunal remains from peninsular India generally occur within a few river valleys notably the Narmada, Son, Belan, Godavari and Krishna and its major tributaries like Manjra, Bhima, Ghod, Wardha, Penganga, and Tungabhadra. Associations with Pleistocene archaeological assemblages are therefore generally rare and challenges exist in correlating the lithic material with fauna. Here we present three localities, two previously unreported, that have yielded several faunal remains within an approximately 5km stretch of the River Bearma. The Bearma is a tributary of the Sonar which in turn discharges into the Ken, a major northeast flowing Central Indian river. The faunal fragments found along this portion of the Bearma consist both cranial (including teeth) and post-cranial elements belonging to mammalian species within families of Bovids, Cervids, Proboscids and Equids. A fossilised mollusc has also been recovered from one of the localities adding to the taxonomic diversity of the overall assemblage. States of preservation vary depending on the duration of exposure, with some specimens being patinated and rolled. All samples were recovered from the active channel of the Bearma, however some seem to have been recently eroded from yellowish-brown silty sediments flanking the river. The presence of cemented gravels at all three localities is noteworthy, with some of the fossils being adhered to these outcrops in the stream bed. While artefacts, mostly small flakes and tools on crypto-crystalline material, have been identified along with the fossils, straightforward associations are challenging owing to the secondary nature of deposits within fluvial contexts. A rich Acheulean locality was also found along the Bearma, an anomaly on this river, just downstream of the fossil localities and associated with the cemented gravels but devoid of faunal remains. Previously researchers have tried to co-relate the Bearma fossiliferous sedimentary sequence with the Central Narmada and Middle Son formations roughly 250kms to the southwest and northeast respectively, bracketing them between the Late Middle and Terminal Pleistocene. Thus this small yet important assemblage from district Damoh holds the possibility to fill in both key geographical and temporal gaps in the paleoanthropological research of Central India.

Human-animal relationships: A Case Study of Dimasa community interpreting their ethno- cultural history & folklores through study of utilitarian involvement of wild and domestic faunas

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The northeastern region of India has diverse ranges of cultural affinities of indigenous ethnic communities. They share a varied quantum of knowledge related to traditional practices, zootherapeutic knowledge and their own curetted hunting and butchering skills of wild faunas. The ethnic community of Dimasa has a close-knit world with the utilitarian concept of involving wild and domestic faunas in their everyday life. The people of the Dimasa community are adept in using animals in every facet through their beliefs of superstations, hunting for, subsistence, pride and security thus making them prone to the modernization surrounding them.

The research focuses on the utilization and valorization of wild and domestic faunas by the Dimasas in traditional zootherapeutic practices, butchering patterns, and mummification of the hunted animals. Along with it usage of animals are also seen in ontological aspect which is an eminent part of their religion, culture, and traditional ethnozoological approaches adopted by the ethnic community. The study aims to draw analogies from the modern hunting activities of the Dimasa which implies primitive practices inherent from previous hunters and gatherers. The social entanglement of the Dimasa society with the animals in ritualistic measures is crucial for the themes of relational archaeology which interprets the connection between the material and human world stating on the cohabiting nature of human and animals evolving from ancient time period. Increasing advancement in the economic sphere has increased their dependency on wildlife resources creating imbalances in the ecological sphere with a decline in the faunal diversity as well. Ethnographic observation of contemporary societies aided with geographical and ecological aids can help us to understand the cultural continuity with respect to the status of conservation of the present species correlating them with the past faunal resources by tracing local ecological diversity of the region.

Dynamic adaptability of core-and-flake technologies: discussions on the evidence from the Indian Subcontinent

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It is postulated that early hominins had behavioural and anatomical capacities to adapt to new situations with their Mode 1 technology, and hence, Mode 1 or simple core-and-flake technology is considered to be a powerful adaptive tool for the hominins. Ecological studies undertaken at various Mode 1 occurrence across the Old World attest to the proposition that a simple 'core and flake' toolkit was an excellent adaptive tool to cope with unfamiliar terrain, wide resource variability and uncertainty. Therefore, such 'opportunistic' and 'least effort' technology continues to appear in the archaeological record along with other advanced technologies and is associated with the earliest occupation of a region. In the present research, we represent evidence from two distinct regions in the Indian Subcontinent: Siwalik Hills (northern India) and central Narmada Valley (central India). The results indicate that at both these locations, local fluvial clasts (pebbles and cobbles) were utilised for the production of lithic artefacts. The primary technology at both these locations is observed to be core-flake, possibly related to the form of locally available raw material. Currently, there are no chronological data from these locations; however, according to previous academic research, there is a hint of Mode 2/Mode 3 in the evidence from Siwalik Hills. Through this research, we try to understand the significance of core-and-flake technology in terms of hominin behaviour and their adaptiveness to various landscapes in the Indian Subcontinent.

Understanding the Palaeolithic occupations of the eastern Thar margins, Chittorgarh, Southeastern Rajasthan, India

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Chittorgarh, located on the eastern margins of the Thar desert, reveals the highest concentration of Late Acheulean sites in the Indian subcontinent. This region represents evidence of enduring climate change and is presently characterised by diverse climatic zones, ranging from arid to semi-arid environments. The undulating topography of this semi-arid region is characterised by the Aravalli, Vindhyan, and Bhilwara supergroups, which are drained by the Berach River and its tributaries. Adequate water, food, and raw materials resources made this area habitable during the Pleistocene. Previous research in this critical geographical region has been limited to restricted surveys along the river banks and lacks a multidisciplinary approach. Despite studies on Palaeolithic occurrences being investigated here since the 1950s, the potential to answer significant questions concerning hominin adaptations in South Asia is less explored, with most studies being restricted to typo-technological studies and descriptive notes of their distributions. Rich and continuous Palaeolithic records ranging from the Acheulean to the Late Palaeolithic have been reported here at various sites. Recent explorations in this area have resulted in the discovery of several Lower and Late Palaeolithic sites in various geological contexts primarily in colluvial deposits of Semri, Kaimur and Bhilwara formations. These sites are spatially distributed in three distinct clusters -Eastern, Western and Southern. In terms of technology, raw material preference, artefact density, and preservation status, each group is distinct from the others. The western cluster represents Late Palaeolithic technologies, while the eastern and southern clusters represent Late Acheulean and prepared core technologies. This paper highlights the lithic variability observed within these clusters of sites as well as the core reduction strategies employed on various sites using the *Chaîne- opératoire* method. Further, it presents the results of the morphometric analysis of the bifacial tools along with a comparison of the results with contemporary assemblages from neighbouring valleys (Luni, Banas, and Narmada) to better understand subsistence strategies, raw material preferences, and adaptation.

Agricultural strategies and adaptation during Indus era in north-western India: implication to human-environment interactions

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The onset of agriculture is one of the most important event for an ever-intensifying human-environment interactions in prehistory. Though agriculture is a human effort but, it has intimate link(s) with contemporary environment. Fossilised organic plant remains recovered from archaeological excavations reveal wealthy information about past agricultural practices and contemporary environment. Macro-botanical analysis along with stable carbon isotope from an Indus era (~2900−1800 BCE) in north-western India revealed how agricultural strategies at these settlements shifted in response to the changing climatic (monsoonal) conditions. The results revealed the transition in the agro-ecological conditions i.e. wetter to drier (arid) during the period of weakening of monsoon (aridity). All together the data revealed that the agriculture during early phase (~2900−2400 BCE) mainly rely on winter season crops facilitated with the winter precipitation, however, the later phase (~2200−1800 BCE) revealed enhanced proportion of drought resistant crops owing to the declining India Summer Monsoon (ISM). $d^{13}C$ of plant remains and soil organic matter also revealed the similar transition in agricultural strategies owing to the aridity ~2200 BCE and later. Abundance of millets at these archaeological settlements might have played an important role in the subsistence economy as an adaptations to the deteriorated climatic conditions due to prolonged weakening of ISM. Overall subsistence pattern indicates continuity and change in temporal domain likely owing to changing environmental conditions over time ~2900−1800 BCE. The cultural adaptation enables consideration of issues related to adaptation and resilience in the face of changing economic and environmental conditions. We surmise that the adverse climatic conditions (declining monsoon) might have compelled settlers to opt for alternative crops resilient to prolonged drought conditions. Present study provides a valuable template for modern societies in exploring plausible strategies to tackle future climate change.

Keywords: Indus civilization, Subsistence, Holocene, Indian Summer Monsoon, Fossil plant remains, Stable carbon isotope

Playas, Fossil dunes and Palaeolithic sites of Thar desert: Geoarchaeological survey in Central Rajasthan, India

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The eastern margins of the Thar Desert have revealed a significant amount of archaeological data related to the Middle and Late Pleistocene phases. During this period, the region experienced sub-humid to arid climatic fluctuations. We have a sporadic presence of artefacts through the desert landscape, whereas high-concentration cultural complexes are only limited to certain pockets. The Late Acheulean and Middle Palaeolithic hominins were probably adapted to grassland-type open-air environments and micro ecozones around lake shores. Some of the previous studies suggest lake shore occupation by Acheulean (e.g., Singhi Talav) and Middle Palaeolithic cultures. Stable dunes are another landform type which was sometimes preferred for habitation (e.g., 16R). This study refers to the previously known context of Palaeolithic sites and seeks to identify new sites within the region. A detailed field survey was conducted to understand the nature of the site distribution pattern. As a result of exploration in associated areas, we found up to a dozen new sites. Our findings confirm that Palaeolithic cultures flourished around the natural pond-like setups and some other sites found in the stable dune deposits. The lithic findings were associated with ecofacts, i.e. fossil bones and bird egg shells, including ostrich and mollusc shells. Further, the study confirms the geological formations of calcrete deposits and fine sediment associated with the archaeological sites. The cultural material exhibits the presence of Acheulean bifaces in a semi-primary context and Middle Palaeolithic artefacts, including tanged points and Levallois core. The most peculiar phenomenon is the miniaturization of lithic objects like diminutive handaxes and micro Levallois cores. This work confirms the presence of palaeolithic sites from previously unknown areas and their firm associations with the paleo landscape and ecofacts. Identifying stratified context, which is rare in the desert landscape, opens up the possibilities of relative dating of the archaeological remains.

Session 56: The Palaeolithic of the Americas: population dynamics, behavioral variability and techno-cultural diversity around the Last Glacial Maximum (MIS 2-3)

The Indigenous Paleolithic of the Western Hemisphere (the Americas)

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The archaeological evidence for human settlement of the Western Hemisphere (the Americas) during the Indigenous Paleolithic (prior to 12-15 k years ago) has been growing for the last century, despite the overly aggressive political debates that created the field as an archaeological research area discussed as an area of academic suicide. Reviewing paleoenvironmental and mammalian migration evidence, it is clear that during numerous interglacial events (2.1M to 24 K years ago), land-based migration routes between the Eastern Hemisphere (Asia) and the Western Hemisphere (the Americas) were available. The evidence from open water crossings on a global scale also supports the possibility of human migrations between land masses prior to 24 K ago. Reviewing published academic literature, I built a database of over five hundred pre-Clovis (pre-11,200 YBP) archaeological sites in North and South America dating from 11.2 k – 200 k years ago. The archaeological record of the Western Hemisphere (the Americas) during the Pleistocene is strikingly diverse, providing evidence of distinct cultural groups' adaptations to varying environments across time and space. I argue that the archaeological, paleoenvironmental and paleontological evidence supports a human presence in the Western Hemisphere prior to 24 K (MIS 2-3) years ago. Recent research has challenged decades-old assumptions regarding early human evolution and migrations in Africa, Europe and Asia. The archaeological, paleontological, and paleoenvironmental evidence that informs our understanding of human settlement in the Western Hemisphere (the Americas) during the Pleistocene is well documented. It is long past time to update the Pleistocene (Indigenous Paleolithic) history of humans in the Western Hemisphere.

New data on Santa Elina rock shelter, Brazil: highlighting its importance for the peopling of the Americas and paleoecology of megafauna around the LGM

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Santa Elina, in Central Brazil, is an important archaeological site in South America. It records successive human occupations from the Late Pleistocene to the Early Holocene with an abundance of megafaunal remains, lithic industry, fire structures, and exceptional rock paintings on the limestone walls of the shelter. Archaeologists have been documenting the site and its material culture for the past 40 years. Here we share new data that reinforce Santa Elina as critical to the debate on peopling of the Americas and their interaction with the now-extinct Pleistocene megafauna. A recent Bayesian age model confirms the well-defined stratigraphy and ancient chronology of Santa Elina; the oldest archaeological unit (III4) is reliably dated to before the Last Glacial Maximum (LGM), around at least 27–25 ka. This unit preserves abundant spatially and temporally associated megafaunal remains (giant sloth bones, *Glossotherium phoenesis*) and cultural remains (stone tools and other lithic industry elements). Isotopic analyses ($\delta^{13}C$, $\delta^{18}O$) performed on teeth fragments of *G. phoenesis* from Santa Elina (unit II2 and III4) reveal their generalist diet and contribute to the paleoenvironmental reconstitution of the site. New AMS radiocarbon dating on bioapatite material of *G. phoenesis* reinforces that unit III4 is dated to around the LGM. Deep investigations using established methods (stereomicroscope, scanning electron microscope) and advanced imaging techniques (microtomography, Photoluminescence, X-Ray Fluorescence) reveal that three ground sloth dermal bones (i.e., osteoderms) of a ground sloth from unit III4 were human-modified into personal ornaments. They present stone tool marks, rim perforation, polish aspect, attachment system, and use-wear traces. Novel analyses indicate that these bones were modified while fresh. This demonstrates the contemporaneity of humans with the Pleistocene megafauna around the LGM. Unfortunately, despite the growing evidence for the peopling of the Americas starting much earlier than ~16 ka, several pivotal Latin American sites (including Santa Elina in Central Brazil and the Serra da Capivara complex in northeast Brazil) are still regarded as contentious, despite their solid evidence. We assert that Santa Elina is a key piece in the puzzle debate of the Paleolithic of the Americas.

Santa Elina rockshelter, or living in the center of South America at the beginning of MIS2

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The Santa Elina site lies in western Brazil, in the state of Mato Grosso. It is a rockshelter located in a vast crevice of the limestone massif of the Serra das Araras. In a stratigraphy more than 3 m thick were recorded the testimonies of successive passages of human groups over a temporal depth of nearly 30 ka. The oldest archaeological level is located in the lower part of stratigraphic ensemble III, composed of sandy sediments and limestone blocks (layer III3/III4). It is dated by several direct methods between 25 and 27 kyrs BP. Human presence is attested by a few hundred lithic pieces associated with the remains of an individual of the genus *Glossotherium* (giant sloth), including several dozen bone fragments and thousands of osteoderms. Three osteoderms show the marks of anthropogenic modifications, particularly by perforation.

The oral contribution that we propose here will be an opportunity to present the first results of a new ongoing study of the lithic industry of this level, all in the general context of this archaeological level. The collection consists of flaked remains of different raw materials, among which dominates very clearly a detrital limestone of a different nature from that of the walls of the shelter. The main objective of this production is to transform fairly standardized light plates, mostly between 5 and 12 cm long, into tools by means of short retouching sequences. The edges and volumes are varied, highlighting different functional intentions. Some recurrences appear, however, such as a particularly marked taste for notches and beaks. These flaked plates represent more than half of the collection. The rest is composed of flakes, most of which seem to come from the retouching of the plates. Some of these flakes have also been turned into tools.

To date, Santa Elina is the only archaeological site with such ancient dating in central South America. Its existence encourages us to no longer look only at the coasts (Pacific or Atlantic coast) to fully grasp the settlement processes of the continent.

Stratigraphy, radiocarbon ages, archaeology, paleontology, and astrophysics: 15 years of research about First Nations in the Pilauco Site, Northwestern Chilean Patagonia.

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Prior to the discovery of the Monte Verde (MV) sites, the only validated archaeological evidence in the Americas was related to "Paleo-Indians", < 12,800 years. Research at MV overturned finally the Clovis-First paradigm, at the Taitao bar, not far from MV, on January 12, 1997. Since then, we have learned much about the lifeways of our true First Nations.

The Pilauco site, located in Osorno, ~100 km north of MV, presents another body of evidences of Pleistocene human presence in northwestern Chilean Patagonia. Here, our objective is twofold: to summary more than a decade of research, and to offer some reflections on Pilaucos' place in Patagonian and continental peopling.

The site was formed on an alluvial plain carved on ancient volcanoclastic strata, where a seasonal wetland was formed. The organic sediments deposited here preserve fossils and archaeological evidence. The latter is made up of cores, flakes, debitage and highly effective stone tools associating affordance, debitage, and shaping. Also, there are two human footprints, perforate seed and stones, and ocher.

This record represents continuous human evidence for 4,800 years between 17,600 and the beginning of the Younger Dryas (YD) chronozone (12,800 cal BP), when the fall of an impactor produces significant environmental, faunal, and floristic changes.

The fossil fauna is composed of extinct (mainly gomphotheres, cf. Notiomastodon platensis) and extants micromammals, accompanied by extinct and extant coleopteran species. The first group disappears from Pilauco site around 12,800 cal BP, the second group lives in northwestern Patagonia until today.

As with the fossil seeds, fruits, and cuticles, pollen assemblages below 12,800 cal BP are diverse and abundant, indicating moderately dense, mostly non-tree, herb-dominated vegetation. This assemblage is formed by mostly hygrophilous and cold-resistant plants, typical of the northern Patagonian Forest.

The consequences YD impact hypothesis are well documented by a significant maximum abundance of platinum, gold, iron spherules and high-temperature iron-chromium particles. A geologically instantaneous sharp increase in charcoal abundance records an unparalleled episode of biomass burning.

15 years of research and a growing corpus of multi-proxy information make Pilauco a key site for the understanding human paleoecology in the Americas.

Away from the coasts and high up in the mountains: cultural and chronological significance of Mexico's Chiquihuite Cave and Sima de las Golondrinas highlander sites within the LGM population dynamics

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Cueva del Chiquihuite (Chiquihuite Cave) and Sima de las Golondrinas (Chasm of Swallows) — two ancient caves located 100 km apart in northern Zacatecas, Mexico — are among the oldest archaeological sites in North America, with well-dated stratified deposits of Late Pleistocene age. Chiquihuite Cave yielded a long occupational history that draws back to the onset of the Last Glacial Maximum (LGM), and is characterized by an interesting lithic industry manufactured on locally-available, recrystallized, fine-grained limestones. Sima de las Golondrinas has so far revealed a younger occupation, spanning from the LGM to the Younger Dryas, in the form of cut-marked bones and possibly the oldest symbolic expressions in North America. Interestingly, the two sites cannot be compared on the same bases, as they don't share the same types of evidence. The artefact assemblages at these localities are relevant for the discussion of cultural diversity in Americas during the LGM. The modified bones inform both of the diet and paleoenvironment, but also of the ideological and behavioral aspects that seem to connect far beyond the American continent. The lithic artefacts have recently started to reveal similarities with other old sites in both North and South America, such as the well-known prehistoric localities in Brazil. Both caves are located on the Northern Mexican Highlands, on different mountain ranges, and at considerable distances from both western and eastern coasts (350-600 km in straight lines), on the central north-south axis of the continent. Chiquihuite and Golondrinas are equally intriguing in the debate of the earliest human colonization of the continent. Were these groups adapted to highland and mountain landscapes instead of riverine and coastal areas? Do they reflect vast migratory cycles that only returned to northern Zacatecas every generation? Are they testimonies of inland peopling routes? Can they be finally related to specific North/South American and (why not?) Eurasian cultural traditions? Were the inhabitants of the two caves the same or at least related groups? And finally: are we looking at the ancestors of later Pleistocene populations or rather at extinct groups that died out?

From MIS 2 to MIS 1 in Colombia : technical and technological data in postglacial times

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The Pleistocene-Holocene boundary (PH) in the Americas is widely characterized from archeology as a transition. However, this notion has been built from geological, geographic and paleoenvironmental/paleoclimatic information. What does it mean first at the archaeological level, and then at the cultural level? Is this "transition" a historical entity in itself? Some of these questions have been raised in North America, but rarely in South America. On a continental scale, this period, roughly between 13,000 BP and 9,000 BP, is synonymous of technical diversity, but where does this supposed diversity begin and end? Overcoming this terminological repulsion by comparing all available data (beyond classical fossils directors such as projectile points) from different disciplinary axes, would lead to a more detailed understanding of Late Pleistocene technical phenomena. This research proposes a critical review of the notion of transition in northwestern South America based on available data and new analyzes of Colombian lithic industries. Human presence in Colombia is recorded in a discontinuous way from 18 k.y. BP. Within the PH boundary, a great technocultural variability is observed, composed of different unifacial and bifacial lithic traditions, different patterns of subsistence and plant settlements/manipulation and domestication. Likewise, from MIS 2 to MIS 1, the Colombian territory is testimony of the succession of several episodes such as the Fuquene stadial (21-14 k.y. BP), the Susaca interstadial (14-13 k.y. BP), the Ciega stadial (13-12.5 k.y. BP), the interstadial Guantiva (12.5-11 k.y. BP), and the stadial Abra (11-10 k.y. BP). These changes added to volcanic eruptions of the last 20,000 years undoubtedly shaped the archaeological record that reaches us to the present. How, then, do human occupation fall within this paleoenvironmental/paleoclimatic context? Can we speak of a causal relationship between technical, cultural and climatic facts? Colombia, formed by a diversity of biomes that transcend current political limits, is key to the understanding of the first South American settlements. From the technical recurrences and differences, preliminarily identified, between recently studied lithic assemblages, a set of technological hypotheses are proposed about the PH boundary's meaning within the context of South American early prehistory dynamics.

Inhabiting the Puna de Atacama before and after MIS 2: the evidences from Cacao 1.A. (Antofagasta de la Sierra, Argentina)

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Cacao 1A (25° 54´46” S, 67°20´27.1” W) is an archaeological site located at 3780 masl near the confluence of Cacao and Curuto ravines, north of Antofagasta de la Sierra (W Catamarca, Argentina). It is a rockshelter developed in early Pleistocene ignimbrites with rock art representations spanning the entire Holocene. The site includes a protected area of 20 m^2 as well as an outer esplanade of loose sand bounded by a silghty sloping semicircular stone wall with a 15 m radius including abundant lithic artifacts on the surface and the subsurface.
The rockshelter sedimentary filling (~1m thick) is composed of a lower layer, archaeologically sterile, made up of loose fine sand deposits, overlain by a compact unit (layer 5) mainly composed of plant remains from megafauna feces disaggregation (Megatherium, Mylodon and Hippidion). Layer 5 which includes the oldest archaeological evidence (mainly lithic artifacts), is dated between 38 000 BP and 40 000 BP. Since 2020, within the framework of a Franco-Argentine archaeological mission, French and Argentine specialists have collaborated closely on two aspects: specialized studies of the material collected during previous excavations and a vast geochronological program whose objective is to confirm the existence of Pleistocene archaeological levels in the region as well as understanding their geomorphological context.
In this work we detail the latest advances corresponding to this collaboration. This site has a complex history, which is why we debate about the position of archaeological materials in the interior of a Pleistocene layer; which will give ages of more than 50 000 BP. Based on the study of typological characteristics of lithic artifacts, the geomorphological context of the deposit and dates obtained in a hearth located at the rockshelter's mouth (15 000 BP and 10 000 BP) we deepen aspects of the associations documented so far, considering the processes of human-megafauna occupation-unoccupation recorded and the role of Cacao 1.A as a refuge in the Puna of Argentina.
These results are compared with other sites at a regional and continental scale, in order to assess the relevance of Cacao 1.A in the Puna de Atacama and in the South American Pleistocene.

Revisiting ancient and new lithic collections from classic South American sites: critical assessment and contributions to early peopling of South America

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1. *Université Paris Nanterre*

The initial peopling of the Americas is a matter of ongoing debate. In an attempt to renew this discussion, we focus on the South American record, generally relegated from continental debates. In this communication we present a revision of the lithic industries of eight archaeological sites (Toca dos Coqueiros, Piauí, Brazil; Cacao 1.A., Antofagasta de la Sierra, Argentina; Arroyo del Vizcaíno, Canelones, Uruguay; Monte Verde, Puerto Montt, Chile; Pilauco and Los Notros, Osorno, Chile; Pikimachay, Ayacucho, Peru; Huaca Prieta; La Libertad, Peru), among the most ancient and significant sites in South America. Based on the 3D technicofunctional analysis of these assemblages dated between 40,000 BP and 13,000 BP, we address the assumed techno-cultural homogeneity assigned to the South American Pleistocene and propose a new conceptualization. Our review mostly deals with: a) chrono-stratigraphy, b) methodological approach for the study of the assemblages, c) the geofact/artifact protocol approach, and the d) technological, evolutionary, and historical interpretation of technical phenomena. Taking into account these and other archaeological and paleoenvironmental data available in South America thus renders currently technical traditions not heuristic at different scales and allows us to propose elements for a more logical paleolithic research in technical and cultural terms. The geochronological, paleoenvironmental and paleogenetic contextualization of our results at the hemispheric level indicates an internal variability in each South American region, allowing us to rethink the role of South America in the first dispersals of *Homo* across the American continent. We finally propose a micro-regional approach to American prehistory, from our perspective the only solution way to address in the medium and long term the Americas population dynamics during the Late Pleistocene.

Bluefish Caves Revisited: A Geoarchaeological and Paleoenvironmental Assessment of a Potential Pre-Clovis Site in the Yukon territory of Northwestern Canada

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1. *University of Kansas*

Bluefish Caves, a cluster of four small rockshelters in the Yukon Territory of NW Canada, was excavated during the 1970s and 80s under the direction of Jacques Cinq-Mars. Caves I, II, and III yielded faunal remains dating to ca. 30-10 ka contained in loess, plus artifacts. Also, AMS ^{14}C ages determined on cut-marked bones identified during a recent taphonomic analysis of the faunal assemblage suggests that humans occupied the site as early as 24 ka. Hence, Bluefish Caves may be the oldest recorded archaeological site in North America, and the findings support the "Beringian standstill hypothesis," which proposes that a genetically isolated human population persisted in Beringia during the Last Glacial Maximum (LGM) and subsequently dispersed from there to North and South America. However, the stratigraphic context of the artifacts and evidence of anthropogenic bone modification have been challenged.

Here, we report results of our recent investigations at caves III and IV. In 2019, limited archaeological testing was conducted at Cave III to gain a better understanding of site formation processes. Also, soil/sediment samples were collected for ancient DNA (*sed*aDNA) analysis to determine the feasibility of isolating and sequencing ancient genetic material of transitional late Pleistocene/early Holocene flora and fauna from subarctic loess. Following initial processing of *sed*aDNA samples, sequences suggest recovery of sufficient nucleic acids for identification of multiple taxa in those samples, thereby providing a more robust picture of LGM and post-LGM paleoenvironments in the region. Also, we relocated Cave IV, which was not excavated by Cinq-Mars. The entrance and interior of Cave IV are almost filled with sediments. In July 2022, we tested the area in front of the cave, exposing a ~1-m-thick deposit of loess containing remains of horse, caribou, and other late-Pleistocene fauna. Many of the bones are being ^{14}C dated, and sediment removed from the test units will be fine-screened for micro-debitage. Also, soil/sediment samples were collected for ancient DNA (*sed*aDNA) analysis, and ongoing micromorphological and sedimentological analyses of the loess will help us gain a better understanding of site formation processes and the spatial integrity of any cultural deposits found in Cave IV.

Distribution of Upper Paleolithic human fossil footprints from White Sands National Park

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In the American southwest conformation for the presents of people from the upper Paleolithic has been obtained from fossil prints of both human and late Pleistocene megafauna. The wet dry episodic events of dry lake beds and salt flats that were once pluvial lakes and ice age wetlands have provided ideal conditions for creating an incredible record of human trace fossils.

This paper will focus on the distribution, abundance, and composition for a variety of fossil prints that have been preserved for over 23,000 years at White Sands National Park. The site at White Sands is important, in that it provides an analog for other pluvial systems that may be preserving fossil prints from the American Southwest or other arid regions of the world. At the upper lake margins there are several meters of stratigraphic sediment containing fossil prints and organics. On the basin floor there are only one to two thin layers with fossil prints. As moisture within the soil is being reduced by persistent droughts and rising temperatures, the prints are rapidly being exposed and lost to soil erosion. For this reason, there is an urgency to document the fossil prints at White Sands and examine other dry lake beds from around the world before the record is lost.

Arroyo del Vizcaíno site (Uruguay): a contribution to the debate of early peopling of the Americas

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In recent years, several sites vied for adding evidence of human colonisation of the Americas prior to the Last Glacial Maximum. Among them, the 30-kybp Arroyo del Vizcaíno site (AdV) in Uruguay yielded over 2,000 remains mostly of megafaunal species. Among other evidence, some of the fossil remains present cut-marks, which further challenges the already dwindling Clovis-first paradigm. Criticisms on the validity of the site as a potential contribution to such debate have centred on the age of the site, the nature of the bone surface modifications (BSMs), the formation of the site and the scarcity of lithic remains. In this presentation, we discuss our research on those controversial aspects. New dates are being obtained in order to improve the chronology of the site to test our hypothesis of a single depositional event. The BSMs have been the subject of careful research since the AdV was first thoroughly described in 2013 through 3d reconstruction. The results were compelling about their human agency, which was further assessed in later studies about possible equifinality as well as approaches that incorporate the use of Artificial Intelligence. The other lines of evidence are admittedly weaker, as a whole model of site formation has not yet been published. Moreover, the lithic remains are still the subject of on-going research. However, these studies are in the process of being completed and the preliminary results suggest that they are consistent with the hypotheses proposed.

Session 58: The new challenges for luminescence dating

A detailed luminescence chronology of the Late Quaternary Caspian Sea history (Lower Volga region, Russia)

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In the last decade, loess-palaeosol sequences and alluvial sediments of the Volga River in the northern Caspian Lowland have been intensively studied. In the Lower Volga valley, a 400 km long outcrop reveals the Middle and Late Quaternary sedimentation history of the whole Caspian Basin. The stratigraphy and paleontology of many reference sections (e.g. Srednyaya Akhtuba, Raygorod, Seroglazovka, Kosika) in this area have been described but most sections still lack a reliable independent chronology. Here we present the first high-resolution luminescence chronology for the 18 m thick Srednyaya Akhtuba section. The section represents the most complete Late Quaternary sedimentation history of the Lower Volga region and is made up, from bottom to top: estuary sediments of the Late Khazarian transgression, a thick (~8 m) loess-palaeosol sequence (Atelian stage), three Volga alluvium units (~4 m), the Late Khvalynian Chocolate Clay unit (~3.5 m) and the modern soil (~1 m thick). Ninety luminescence samples were collected over the entire sequence and both multi-grain quartz OSL and feldspar post-IR IRSL dating was applied. We present extensive luminescence laboratory tests to support the reliability of both the quartz and feldspar ages. A time-dependent water content model was developed taking into account the complex drainage history of the site. The dating results reveal that the last ~130,000 years of sedimentation is recorded at Srednyaya Akhtuba. The resulting age-depth model shows that there were no significant breaks in sedimentation and that there is a clear dust accumulation peak at ~65 ka (MIS4).

A revision of the British Chronostratigraphy within the Last Glacial-Interglacial Cycle based on new evidence from Arclid, Cheshire UK.

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There is large uncertainty regarding the timing and nature of British interstadials during the Last Glacial-interglacial cycle (LGIC) due to the fragmentary preserved evidence. Of the 24 Greenland interstadials (GI) in the LGIC only five are formally recognised in Britain. Sites which do detail British interstadials during this period are spatially disparate and often lack a robust chronology relying on biostratigraphy or radiocarbon ages based on old techniques. Where sites do span the LGIC and have good chronological control sedimentation appears to have been episodic rather than continuous.

This paper aims to improve understanding of the LGIC in Britain by focussing on a site at Arclid, Cheshire where thick aeolian and fluvial sediments (>25m) containing organic deposits have the potential to cover the entire LGIC. The site sediments were characterised, luminescence dated and organic deposits underwent fossil insect analysis. The stenothermic species from the latter were compared to other sites in England to better understand similarities between interstadial conditions . Results show sand was deposited at the site initially by aeolian but later by fluvial and then fluvioglacial transportation between 77-33 ka ago. Coleoptera and Diptera from an organic lens provided a reconstruction for a heather rich heathland environments grazed by large herbivores, with summer temperatures between 13-18° C, and winter temperatures between -14 and 1°C.

Stenothermic beetle analysis from Arclid indicate similarities with results from other British mid LGIC sites, some of which are at or beyond the limit of radiocarbon dating and may instead be of a similar age to Arclid. A revised British chronostratigraphy places the Chelford, Brimpton and Cassington Interstadials within GI 22/23, GI 21 and GI 20/19. Basal organic sediments found at Arclid are assigned to GI 16 with the Arclid mid and upper peats tentatively assigned to GI 14 and GI 13. This removes the gap in interstadials between the Brimpton Interstadial and the Upton Warren Interstadial complex within the British chronostratigraphy.

Feldspar luminescence dating sheds new light on Pleistocene depositional sequence in an uplifted coast, eastern Japan

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Feldspar post-infrared infrared stimulated luminescence (pIRIR) dating is a popular method for determining sedimentary ages that range from a few thousand to several hundreds of thousands years. Its potential is however yet to be fully explored for a range of sedimentary archives. We hereby document a thorough application of feldspar pIRIR dating to depositional sequences in an uplifted coast, eastern Japan and how it refines our understanding of stratigraphic evolution in responses to glacial sea-level changes and tectonics. The depositional sequences are present beneath the Last Interglacial raised marine terrace in the Kanto Plain, eastern Japan, corresponding to transgressive-regressive cycles since the Middle Pleistocene. In the northeastern Kanto Plain, the marine terrace has been believed to represent a coastal barrier during the MIS 5e sea-level highstand, whereas the chronology of the underlying stratigraphy has not been constrained. Our new investigation of two drill cores and four outcrops identified c. 30-m-thick depositional sequences of sandy and/or gravelly marine and terrigenous sediments. More than 50 sediment samples were collected from the sequences for pIRIR dating. According to pretests, the pIRIR at 225□ after a prior infrared stimulated luminescence at 50□ was found to be optimal and thus used for the age determination. The lower part of the sequences consists of MIS 7 shallow-marine deposits, MIS 6d shallow-marine deposits, MIS 6a–c fluvial deposits, thin MIS 5e shallow-marine deposits, and MIS 5d fluvial to brackish deposits, being overlain by coastal barrier deposits with the maximum elevation +30 m. Ages of the coastal barrier deposits are around 110 ka, most likely correlated with MIS 5c rather than 5e as considered previously. This revision revises up the regional uplift rate as c. 0.5 m/ky. The marine deposits in relation to the interstadial sea level in MIS 6d has rarely been identified elsewhere and its elevation is consistent with the revised uplift rate. Our pIRIR ages define 100-ky glacial cycles of depositional sequences since the Middle Pleistocene and provide unpreceded insights on stratigraphic evolution in relations to higher-frequency sea-level oscillations younger than 200 ka.

Application of Rock Surface Luminescence dating on different Pleistocene rocky shore marine features.

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Rocky coasts are erosional environment resulting from the landward retreat of bedrock cliffs at the shoreline. These represent over 80% of continental and island coasts and consist of mixed consolidated or unconsolidated gravel sediment, abrasional shore platform and marine terraces. Despite their wide distribution and importance for the sea-level history and tectonic reconstruction, the chronology of their development remains poorly constrained and understood because of insufficient investigation and the limited available direct dating method. In the last ten years, a new luminescence method called Rock Surface Dating (RSD) has been developed to date of last exposure to the daylight of cobbles and rock surfaces. In this work, we test the performance and relaibility of RSD method on different Marine Isotopic Stage MIS5e (117-126 ka) Sardinian marine terraces. Specifically we aim to compare the results from abrasional shore platform, cobbly beach outer frame and the imbricated zone/beach berm deposits. Preliminary results on the abrasional shore platform show good luminescence performance and promising profile shapes. Despite cobbles from the outer beachframe suffer of an important partial bleaching, leading to a high rate of cobble rejection, a reliable burial age of 131 ± 8 ka has been gained. The cobble of storm berm shows the best luminescence performance with a fully reliable final age of 126 ± 9 ka. Results suggest the dependency of RSD performance on the shore environment related to a complete or incomplete exposition of the cobble or erosive surface to sunlight. However, obtained ages are in good agreement with previous ages for the sites, which confirms the good performance of RSD for dating Pleistocene rock surfaces and different rocky shores forms.

Construction of a Bayesian chronology for ocean core LC31 using radiocarbon and luminescence ages to aid the identification of tephra and sapropel marker horizons

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The Eastern Mediterranean is an important region for palaeoenvironmental research because it is sensitive to a complex pattern of climatic and environmental change, influenced by orbital forcing and multiple feedback mechanisms, during the late Quaternary. It is also a key region for understanding the dispersal of humans out of Africa. Consequently, it is essential to develop robust chronologies for palaeoclimatic, environmental and archaeological records in the region, to allow synchronisation and comparison between records and hypothesis testing. Event horizons, such as tephra and sapropels in marine sequences, play an important role in correlating and synchronising the regional palaeoclimatic, palaeoceanographic and archaeological archives.

We have constructed a Bayesian age model for a marine core LC31 based on radiocarbon and luminescence dating. This is the most thoroughly dated and integrated late Quaternary marine sequence in the Eastern Mediterranean basin, which provides opportunities to investigate the event horizons (tephra and sapropel) for the region. Our results suggest that correlation of event horizons can sometimes be ambiguous, leading to erroneous interpretations of palaeoenvironmental data. Tephra representing unknown eruptions could be mis-identified as previous known eruptions if identification is based solely on their geochemistry. Sapropels, unique stratigraphic markers deposited and developed across the Eastern Mediterranean, suffer from ‘’ghost” (invisible) and/or missing sapropels, due to complex depositional and sedimentary processes. Consequently we propose that direct dating of deep-sea sediments via luminescence techniques is an important tool in validating chronologies produced using “known age” horizons such as sapropels and (crypto)tephra.

Post Violet-Infrared Stimulated Luminescence (pVIRSL) Dating: A new luminescence protocol for dating K-Feldspars

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Luminescence dating using quartz provides reliable ages up to ~50-100 ka beyond which, the luminescence signal saturates. Feldspar provides an attractive possibility due to its higher luminescence sensitivity and high saturation dose of ~1000Gy. These offer prospects of a continuous dating range from a few years to up to a Ma. However, a key stumbling block in the use of feldspar luminescence has been athermal loss of luminescence due to quantum mechanical tunnelling (also termed as anomalous fading). This leads to underestimation of ages and thence limits its applicability. Current correction procedures for such fading can deal with sediments up to 40-50ka. For older sediments procedures are still under development.

We explored an alternative route to isolate non-fading component from feldspar luminescence and reported that post violet IR stimulated luminescence (pVIRSL) has a near zero fading (g=0.0 ± 0.1% per decade; Devi et al. 2022). This presentation extends this work and will discuss results on experiments to characterize of centres participating in pVIRSL and properties of pVIRSL in respect of dating applications. An optimized protocol for equivalent dose estimation has also been developed.

pVIRSL shows a rapid bleachability (<10% in 60 min), high saturation dose (~1000 Gy), low recuperation (<5%), high signal reproducibility (<5-10%), good dose recovery (within 10%) beside near zero athermal fading. Use of optimized regeneration protocol on feldspars from samples from diverse environments gave pVIRSL doses in the range, 11 - ~ 500 Gy (ages in range 4- 270ka). These accorded with geological/archaeological reasoning and independent age controls.

Insights from playing with portable luminescence readers in two continents and four laboratories.

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Portable luminescence (port-OSL) readers are powerful tools within trapped charge dating. High-resolution profiles with depth can contextualise sediment stratigraphy, with insights into (i) relative age, including the position of depositional unconformities, and also: (ii) variations in sediment composition (owing to provenance and/or weathering), (iii) variations in the completeness of luminescence signal bleaching (signal resetting before transport). In simple sedimentary systems, with broadly homogenous sediment provenance, it is possible to produce generalised chronologies that approximate sediment burial age.

Our approach is to compare port-OSL signals with established ages using standard luminescence dating protocols and construct calibration curves (e.g. work published in 2019 by Stone et al.). Dryland dunefields have well-bleached aeolian sediments, making them an ideal testing ground. In southern Africa, we have found these port-OSL calibrations are region specific, with consistent and coherent grouping of samples from the Namib Sand Sea (n=26) and for three different parts of the Kalahari (n=66, n=38 and n=18). The calibration approach also shows promise in the Thar Desert, India (n=44) (research by Nitundil as part of MSc dissertation). A change to the approaches taken in the port-OSL sequences and data processing during our investigations means the available portion of the southern African samples are being re-measured to facilitate an intercontinental comparison. We aim to present this intercontinental comparison.

Our experiences with port-OSL measurements on lake shoreline sediments in the middle Kalahari show weaker correlations than for dunefields and suggest sediment characteristics other than burial age drive differences in port-OSL signals in this setting. To test this, we have made measurements on a range of the subsamples from southern Africa to establish the response of bulk sands to a known 4 Gy dose in order to examine whether samples between regions have different inherent luminescence sensitivity. This may also give insights into sand provenance and sediment pathways.

Climate variability in a subtropical desertic area: Lanzarote over the past 125 ka

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Lanzarote is the easternmost volcanic island of the Canary Archipelago located in the Atlantic Ocean with a subtropical hot desert climate (BWh). The very low precipitation (100–250 mm/a) is related to its geography (130 km off the coast of NW Africa) and to the low elevation of the island (~670 m a.s.l.).
Despite the dry conditions, a suite of colluvial fans eventually evolving in debris-flow and water-flow dominated alluvial fan systems developed along the flank of the Famara cliff and on the eastern side of El Jable Plain (NE part of the island). The alluvial fan deposits are partially covered, lateral or cut by wind-blown sandy sediments becoming dominant toward the centre of the plain. Fans merged in a low-land depositional area identified as a possible ephemeral lake.
Lanzarote past climatic evolution was detected through the sedimentological study of alluvial fan and associated dunes. The depositional events were dated using both luminescence and radiocarbon ^{14}C dating techniques.
Results show that depositional area of Famara evolved from the beginning of the Last Interglacial (Marine Isotopic Stage-MIS 5) to the Holocene (MIS 1). A first generation of dune system was present at the base of the escarpment during MIS 5e, whereas through MIS 5d and MIS 5a alluvial fan developed partially covering and/or cutting the aeolian system. A well-developed second generation of dunes (mostly climbing) and a minor development of alluvial fans dominate the first part of MIS 4. Alternate of alluvial and aeolian deposits mostly characterized the MIS 3. During MIS 2 alluvial fans become the dominant depositional system.
The geochronological reconstruction of El Jable depositional system allows the following climatic consideration: wetter conditions are observed during the climate deterioration phase occurred during MIS 5d and MIS 2 glacial periods. During MIS 4 dry climate dominate. High frequency climatic oscillations are the main depositional motive of MIS 3 during which alternate of wet and dry conditions occurred. These allowed the formations in the central part of the plain of ephemeral lakes and, therefore, of mud deposits that where substituted by and sand-sheets during the dry, possibly colder phases.

Session 59: Past, present and future ice-ocean-atmosphere interactions between the Southern Ocean and the Antarctic Ice Sheet

Last Interglacial subsurface warming on the Antarctic shelf triggered by reduced deep-ocean convection

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The global mean sea-level was likely 3 to 6 m higher at the Last Interglacial (LIG) compared to pre-industrial (PI), with an Antarctic contribution estimated at 3 to 5 m sea-level equivalent. Antarctic ice-sheet modelling studies suggest that such an ice-mass loss from Antarctica requires a subsurface warming on the Antarctic shelf of ~3°C compared to PI. Here we show that such a subsurface warming is simulated in an equilibrium experiment of the LIG performed with a comprehensive Earth System Model. Reduced deep-ocean convection in the Weddell and Ross Seas, arising from reduced sea-ice formation, are the primary drivers of this subsurface warming, reaching 2.4°C at 430 m depth. The associated changes in meridional density gradients and surface winds lead to a weakened Antarctic Circumpolar Current but strengthened Antarctic Slope Current, which further impact subsurface temperatures around both East and West Antarctica, with a maximum warming of 3°C at 125 m depth on the East Antarctic shelf. Higher SST and reduced sea-ice formation in the Southern Ocean thus increase ocean stratification and lead to a subsurface warming on the Antarctic shelf, with the potential to trigger ice-mass loss from the Antarctic ice-sheet.

Warm water inflow induced Holocene deglaciation in Lützow-Holm Bay, East Antarctica

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Recent observations and model simulations show that the inflow of warm Circumpolar Deep Water (CDW) causes rapid melting and thinning of the ice shelves of the West Antarctic Ice Sheet, contributing to the ongoing increase in discharge of grounded ice and to sea-level rise. This process is also thought to contribute to the deglaciation of the West Antarctic Ice Sheet after the Last Glacial Maximum (LGM) ca. 21 ka. However, unlike West Antarctica, the role of the CDW in a potential large-scale ice-mass loss in the East Antarctic is largely unknown. In this study, we present a new, well-constrained ice retreat history for the period since the LGM for Lützow-Holm Bay, East Antarctica, based on a detailed geomorphological survey and ^{10}Be and ^{14}C surface exposure dating of erratics and bedrock. The results show that ice sheet melting in Lutzow-Holm Bay began in the southeastern part of the bay along the Shirase submarine valley from ca. 9 to 5 ka and eventually spread to the northeast ca. 8–4 ka. Regional high-resolution oceanographic modeling shows that the current warmer ocean temperature in the southeastern part of the bay results from the inflow of warm CDW via the submarine valley. Thus, these oceanographic and bathymetric characteristics likely caused the asymmetric early to mid-Holocene deglaciation in Lützow-Holm Bay, East Antarctica.

High precision reconstruction of δ13C-CO2 and major greenhouse gas concentrations (CO2, CH4 and N2O) over marine isotope stage 9 – first application of a novel method

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Ice cores are natural archives preserving valuable information of past atmospheric greenhouse gas concentrations (CO_2, CH_4, N_2O) and the changing climate system. To understand how the complex changes of biogeochemical cycles will respond in the future, we need to decipher the role of changing greenhouse gas concentration and the rearrangement within the major carbon reservoirs (ocean, atmosphere, terrestrial biosphere, and sediment) in the past.
Due to the differences in the carbon isotopic composition of the major carbon reservoirs, respectively the carbon fractionation occurring during exchange processes between the reservoirs, $\delta^{13}C$-CO_2 measurements are a useful tool to help disentangle the causes of CO_2 variations driven by biogeochemical processes.
Here we present the first application of a novel extraction and analysis system for simultaneous quantification of CO_2, CH_4, N_2O as well as $\delta^{13}C$-CO_2 in ice core samples. This is achieved by a semi-continuous laser-induced sublimation extraction technique, developed to liberate 100% of the trapped gases from the ice, followed by the analysis of the extracted air samples by a custom-made Quantum Cascade Laser Absorption Spectrometer (QCLAS), especially designed for small air samples of 1–2 mL STP. While achieving a very high vertical continuous sampling resolution of 1.5 cm of ice, equivalent to a 10–15 g ice core sample, our measurements demonstrate an excellent reproducibility (1σ) for CO_2, CH_4, N_2O as well as $\delta^{13}C$-CO_2 (1 ppm, 4 ppb, 2 ppb and 0.03 ‰). Both methods and instruments were developed to achieve such high vertical resolution and highest precision, imperative, to decipher high-resolution carbon cycle changes in the extremely thinned sections of the future Beyond EPICA – Oldest Ice Core (BE-OIC).
Using the novel method described above, this work will present the first high-resolution $\delta^{13}C$-CO_2 record covering the glacial – interglacial termination (T_{IV}) of marine isotope stage (MIS) 9c–10a (332–345 kyr BP). In addition to that, the major greenhouse gases CO_2, CH_4 and N_2O were measured simultaneously. The results of this study will shed light on the mechanisms behind the CO_2
overshoot during early MIS 9.

Glacial to interglacial ocean circulation, sea ice and ice sheet dynamics over the last 140 k y in the Adélie Land region, East Antarctica

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Present-day observations suggest global warming is influencing Southern Ocean circulation and the duration of sea ice, which is contributing to enhanced Antarctic ice sheet melt. Therefore, understanding the functioning of these three parameters, atmosphere-ocean-sea ice, during past climatic transitions, deglacials and glaciations, may provide clues to the extent of future ice sheet stability. In this study we analyse two sediment cores collected from off Adélie Land, one from the continental shelf and the other from the slope. The shelf core presented a sequence of sedimentary facies, and based on the Antarctic ice sheet retreat model (glacial till-glacimarine sediment- open ocean sediment), it revealed the ice sheet retreat from the outer continental shelf in the region occurred at ~14 k yr, giving way to a prolonged ice shelf calving stage which occurred from ~12 k yr- ~8 k yr. Based on the grain size, ice shelf calving had given way to strong bottom currents which were potentially propelled by the initiation of Adélie Dense Shelf Water. The slope core showed a pattern of glacial to interglacial facies changes, including deglacial and glaciation. Based on diatom assemblages, and the presence of *Thalassiosira lentiginosa*, we suggest the last glacial (MIS 4-2) offshore Adélie Land is characterised by an open ocean environment with respect to sea ice. However, based on the increasing presence of *Fragilariopsis obliquecostata*, we conclude the last glacial had a gradual build-up of sea ice. This sea ice duration reached its maximum at the end of MIS 2, before it rapidly vanished. Following this event, based on the presence of *Thalassiothrix antarctica* within the deglaciation facies, we conclude Circumpolar Deep Water (CDW) influx increased over the slope. Finally, based on the ice rafted debris- rich interglacial facies above, we conclude the CDW increase occurred prior to regional ice sheet retreat. Together these datasets suggest major sea ice changes occurred during the last glacial and its end, followed by oceanographic changes, and then by ice sheet retreat, suggesting a progression of events may influence the demise of the East Antarctic ice sheet.

Tracking Antarctic Intermediate Water dynamics in the South Atlantic through the ‘cold water route’ during the last deglaciation

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The circulation of intermediate waters play an important role in global heat transport and carbon storage in the ocean. Changes in their distribution are closely tied to glacial–interglacial climate change. The oceanic gateways of the Drake Passage and Agulhas Current are critical locations for the inflow of intermediate-depth water masses to the Atlantic, which contribute to the shallow return flow that balances the export of deep water from the North Atlantic. Despite being one of the most important water masses of the world’s ocean, the role of the Antarctic Intermediate Water (AAIW) in the Atlantic Meridional Ocean Circulation during various climate states is yet to be fully understood, particularly the cold, low salinity limb that flows through the Drake Passage, known as the ‘cold water route’.

We present a reconstruction of AAIW dynamics through the cold water route over the last ~25 kyr from IODP Site U1534C, located on the Falkland Plateau, which is today bathed in AAIW. We take advantage of ultra-small sample (6-8 specimen) benthic-planktic foraminiferal-derived radiocarbon ages, coupled with benthic foraminiferal $\delta^{18}O$ and Itrax elemental data to track sub-millennially-resolved changes in water mass distribution and ventilation, as well as bottom water current strength at the core site. Using the MICADAS accelerator mass spectrometer at UNSW, our small-sized graphitised foraminiferal samples (200-300 µgC) show precision and reproducibility comparable to full sized (1000 µgC) targets. Results suggest substantial changes in AAIW dynamics and water mass ventilation during the last deglaciation, impacting Atlantic Meridional Ocean Circulation and underscoring the critical role that the Drake Passage plays in global climate during glacial-interglacial transitions.

Antarctic Peninsula surface mass balance since 1600 CD

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Antarctic snowfall, or surface mass balance (SMB), has a direct and measurable impact on global mean sea levels (GMSL). The snow accumulation recorded in Antarctic ice cores has been used to demonstrate a significant increase in SMB during the 20th century, enough to mitigate sea level rise. However, the role of SMB on future ice sheet dynamics is not well understood. Some studies predict that increased SMB may compensate for future Antarctic ice loss, while others predict greater discharge resulting from increased SMB.

One of the most dramatic 20th century SMB increases is observed in the Antarctic Peninsula. In this study, we present an updated record of SMB from the Antarctic Peninsula, including four new ice cores from Palmer Land, the English Coast and Ellsworth Land. This new compilation extends our understanding of SMB variability back to 1621 CE. We also include the first snow accumulation record from Peter 1st island, providing a unique opportunity to explore SMB variability across the Bellingshausen Sea over recent decades. We demonstrate that the role of oceanic and atmospheric dynamics is different at different elevations, highlighting the importance of investigating SMB variability at local and regional scales. The increased SMB over low elevation sites, and a steepening of the SMB gradient, has implications for dynamic ice discharge and future sea level predictions.

Session 60:
Geoarcheology and paleoenvironmental evolution of the coastal areas

The first extensive groundwater-harvesting agriculture in aeolian sand? Early Islamic Plot-and-Berm agroecosystem by ancient Caesarea, Israel

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The "Plot-and-Berm" (P&B) agroecosystem at the southern outskirts of the ancient town/metropolis of Caesarea, Israel, appears to be one of the earliest administrative efforts to cultivate inert aeolian sand. P&B agroecosystems are agricultural utilizations of a shallow water table within loose, aeolian sand, comprised of a checkerboard array of ~hectare-size agricultural plots sunken between 3-10 m high berms. They were developed in agricultural hinterlands with arid to Mediterranean climates. Beyond the southeastern Mediterranean coast, P&B agroecosystems sporadically appear in Iran, Turkmenistan, and Iberia. They are abundant in two regions of Saharan Algeria. Historically dating to the Middle-Ages to early Modern times, some are partly active. Based on a survey of modern-day analogues – Massieras in northwest Portugal, it seems that the plots usually enable 3 agricultural cycles per-annum yielding a wide range of vegetables. The wind-shielded plots probably enhanced micro-climatic conditions for agriculture.

We summarize surveys and three geoarcheological excavations of the Caesarea agroecosystem. Imported fine-grained refuse from adjacent dumps of Caesarea enrichen the plot sand forming 30-50 cm thick, grey anthrosols. The anthrosol level enables year-round access by wells to ~1 m deep groundwater for manual irrigation. OSL ages of the anthrosol suggest a ~250-yr span of agriculture practice during Early-Islamic to early Crusader times (9th-early-12th centuries a.d.).

An anthrosediment made of sand mixed with refuse and hand-size artifacts dating to Early-Islamic times coat and protect the berm from erosion. The berm interior includes sand mixed with small amounts of refuse. POSL profiling indicates a single-stage construction effort. A limekiln and small structures on the berms possess similar OSL chronologies of the berm interiors and anthrosols. Sparse artifacts were found in these features.

Medieval Arabic agricultural manuals and other literary sources lack documentation of this agrotechnology. Based on geospatial-based calculations of the volumes of sand needed to be transported, ~1 million working days was required to construct the agroecosystem. A regional governance probably supported the development of these agroecosystems, possibly in response to religio-administrative calls for *mawāt* (Arabic: "dead") land reclamation. This effort was probably combined with an economic incentive and/or growth of a rewarding crop.

A multi-proxy paleoenvironmental study of a Neolithic coastal landscape. The case of the Cagalell littoral marsh (Barcelona, NE Iberia)

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The study of the past relationships between human communities and their environment is a complex task itself. In coastal areas, this becomes a challenging endeavour since coastal environments are especially dynamic, highly sensible to climate-related environmental changes and they record continuous land use since ancient times. The PaleoBarcino project explores these transformations in Barcelona city from a transdisciplinary, multi-proxy and microscale approach in order to overcome the fragmentary recovery of paleoenvironmental and archaeological data associated to the characteristics of the urban context under study. Furthermore, the project studies human adaptations to coastal changes during the Holocene.

Paleogeomorphological studies performed in the Barcelona Plain have contributed to identify the existence of ancient marshes along this narrow coastal plain during Neolithic times. Understanding the relationship between Neolithic communities and these littoral water bodies is crucial, due to their potential to shape settlement distribution, land use and the availability of freshwater resources. At the same time, marsh records register the impacts and transformations triggered by these farming communities at a microlocal scale. The Cagalell is one of these littoral paleowetlands, with lacunar deposits dating back to 8260-7070 cal. yr BC. It was located between two littoral promontories, the *Mons Taber* (NE, 16 m.a.s.l.) and Montjuïc (SW, 185 m.a.s.l.), and had a maximum expansion of 20-25 ha. Prehistoric occupations are recorded in the area surrounding the wetland from the Early Neolithic to the Iron Age.

We present the paleoenvironmental and paleogeomorphological study of the Cagalell marsh deposits integrated with the surrounding archaeological data. Multi-proxy paleoenvironmental analyses include pollen, non-pollen palynomorphs, ostracods and other micro- and macroremains. The geomorphological and sedimentary studies integrate paleoenvironmental sequences, geotechnical records, and archaeological deposits. A chronological framework for the evolution of the lacunar environment is defined by 16 radiocarbon dates.

This study offers a comprehensive description of decadal to centennial coastal and landscape transformations occurred at the arrival of the first farming communities in the Barcelona Plain. For the first time, both non-pollen palynomorphs and ostracod analyses complement the fossil pollen record from the Barcelona Plain, furthering the understanding of the relationship between coastal wetland environments and these societies.

Modelling the chronologies for the origins and spread of agriculture in the East Asian coastal regions

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After the rise of eustatic sea level slowed down in the early Holocene, coastal wetlands developed across the globe and attracted early communities to settle down, benefitted from the prograding shorelines, increasing land area, readily available water resources, and transitional habitats across a wide range of salinity. East Asia is a prime example of such coastal settling, where two global centres for agriculture – the Bohai Coast and Hangzhou Bay regions – appeared along the coasts in, respectively, northern and southern China since the early Holocene. The current study examines the chronologies for three key domesticates, rice (*Oryza sativa*), millets (*Panicum miliaceum* and *Setaria italica*), and wheat (*Triticum* spp.), in East Asia, to map the establishment of agricultural societies, applying Bayesian and spatio-temporal modelling techniques on radiometric dates. The earliest evidence (ca. 7430 BCE) of rice exploitation appeared in the southwestern margin of the Hangzhou Bay region. Rice appeared in the middle Yangzi River and the Huai River in, respectively, ca. 6680 and 6650 BCE, possibly indicating an expansion of farming communities. Two other major episodes of spread of the crop took place in the period between 4th and 3rd millennia BCE and the period between 1st millennium BCE and 1st millennium CE. The latter episode, including a northeastern spread of rice to the Korean Peninsula and Japanese Archipelago following the coastlines, is linked to major cultural transitions, e.g. the transition from the Jomon to the Yayoi. Millet-based farming seems to have started from the East Asian fertile crescent in the Bohai Coast around 5800 BCE. The spread of this crop should have shaped the formation of the Sino-Tibetan language family. Wheat, a Southwest Asian domesticate, is likely to have been spread to China through the Eurasian steppe and first appeared in the Bohai Coast around 2600 BCE, as an exotic good for the elites. The proposed chronologies refine our understanding of the developments of agriculture and provide essential data for examining the interactions between prehistoric societies and Holocene environmental changes in East Asia.

Pollen and Non-Pollen Palynomorphs to detect the anthropogenic impact in the Mar Piccolo (Taranto, Southern Italy) during the Late Holocene

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The Mar Piccolo area has been settled since the Bronze Age whereas the history of its more close center Taranto dates back to the 8th century BC when it was founded as a Greek colony (Taras). Pollen and Non-Pollen Palynomorphs from a core (S05B, 29.49 m thick)) retrieved in the Mar Piccolo basin allow to investigate the paleoenvironmental changes, including those associated to the progressive increase of the anthropogenic impact, during the Late Holocene. Palynological data provide indication on the crops (e.g., Cereals), land use (e.g., *Olea*), farming (e.g., *Sporormiella*-type) and human/domestic animals presence (e.g., *Trichuris* sp.). They are expressed as: i. percentage of single taxa (e.g., *Olea*, *Vitis*, Cereals), ii. anthropic indexes (e.g., Regional Pastoral Index; Anthropogenic Nitrophilous Herbs), iii. concentrations of NPPs having a clear anthropic origin (e.g., *Trichuris*, *Ascaris*). Starting from 10.74 m a concomitant presence of Cereals, *Trichuris* and *Ascaris* attests the presence of settlements in the Taranto area at least since the Bronze Age. The continuous increase in *Olea* and anthropic NPPs highlights an increase in human activities around the basin possibly during the Greek and Roman periods. A subsequently notably increase of agriculture and herding activities during the Middle Ages is attested by both the great abundance of *Olea* and high concentration in *Trichuris* and *Ascaris*. During this time, historical events as famine, wars, or barbaric invasions are in fact well expressed by the percentage changes of some key taxa (e.g., *Olea*). The regional anthropic impact during the historical time, is also evaluated and compared to that recorded in the closest areas (e.g., Lago Alimini Piccolo). Worthy of note is the finding of pollen grains such as *Daphne caucasica* and *Citrus medica* which provide relevant information on chronology and trade.

Living in a coastal swamp: from a dynamic natural to a dynamic cultural landscape

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In the wide Dutch coastal plain, peat swamps dominated throughout a major portion of prehistory. Still the role of peat growth and subsequent peat degradation in the geological evolution and habitation history is not well known. For this, new palaeolandscape reconstructions were made, integrating new and existing (geo)archaeological and geological data for two estuaries in the western Netherlands.

The occurrence of peat types around the Old Rhine river and the Oer-IJ estuary could be related to environmental factors, such as tidal and fluvial influence. It is shown that peat formation, in return, strongly determined tidal basin infilling, tidal creek position and fluvial style, all strongly steering habitation and land use possibilities. Habitation and initial reclamation often started on higher tidal creeks or on drained edges of the swamps in the Iron Age, and was often followed by local land subsidence and even drowning. Archaeological, historical and geomorphological evidence shows that peat compaction and excavation over the past 2000 years led to subsidence on an increasingly larger scale. This marks the transformation to new human-dominated landscape. It famously put much of the Netherlands below sea level, which led to increased vulnerability of storm-surge ingressions and current sea-level rise.

These insights help to understand reclamation and subsidence history, and furthermore to learn from past adaption strategies to environmental changes that lay ahead.

The ancient Ancylus Lake and Littorina Sea shores of the Vidzeme coast of Latvia, Eastern Baltic: A foundation for coastal Stone Age settlement suitability modelling

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Due to the glacio-isostatic adjustment (GIA) of the Baltic basin region and the global water level fluctuations, the ancient shores of the Baltic Sea development stages can be discovered both underwater and elevated well above the present day sea-level. Throughout Holocene, the dynamics of the ancient coasts have affected the inhabitants of the territory of Latvia; recurrent occupation of several suitable stone age settlements has been noted in previous research, but no notable discoveries have been made on the ancient shores of the Vidzeme coast of Latvia, Eastern Baltic Sea. Since the distance to the coast has often been set as a determinant for the development of early settlements due to the available resources of the sea, e.g., fishing grounds, it is crucial first to reconstruct the possible configurations of the ancient shores. Only several geomorphological studies from the past century have indicated the approximate locations of some of the possible shoreline positions, but a detailed assessment of the past dynamics of the shorelines is lacking.

By implementing a previously developed automated free and open source software workflow (*QGIS*, *SAGA GIS*, *GRASS GIS* and *WhiteboxTools*) on a LiDAR-derived digital elevation model, the traceable ancient ridges of the Vidzeme coast of Latvia are detected and adjusted in raster format according to a GIA model and a relative sea-level (RSL) database for Ancylus Lake and Littorina Sea stages. Each of the adjusted rasters is clustered for trend surface analysis to obtain several ancient water levels per development stage, which are then analyzed for coherence with the input data and general validity with the development of the Baltic Sea.

Similar approach has already aided with archaeological interpretations elsewhere on the coast of Latvia, where settlement sites have been discovered and dated, and it is believed that it could help with interpretations of stone age settlement sites inland, relatively near the Vidzeme coast, where, e.g., seal remains have been discovered. The reconstructed ancient shore models, consisting of several RSL height models, could potentially aid in settlement suitability modelling and lead to discoveries in a relatively unknown land.

Neoarabia, a diachronic multi-scale and multi-proxy approach to East Arabian climate-environmental variability in the Middle Holocene: impacts on coastal Neolithic societies and socio-environmental responses.

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NeoArabia is an interdisciplinary and multi-scalar project, dealing with the very long term of the Arabian coastal Neolithic (6200-2800 BC) by a latitudinal transect of ~1000 km. Focused on environments/landscapes reconstructions and the mobility of human communities, it intends to test the societal resilience at scales from the site to the region, using socio-environmental scenarios. It simultaneously studies paleoclimatic, paleoecological and archaeological changes and variabilities allowing the reconstruction of environmental and societal changes during the Eastern Arabian Neolithic (8500-4500 cal BP). This study is therefore multi-site, multi-scale temporal (seasonal, interannual, millennial, orbital…) and spatial as it is based on a 1200 km latitudinal transect between the southern Arabian Gulf and the southern Arabian Sea (Dhofar) (25.5°N-55.6°E to 16°N-53.45°E).
Our work is based on the simultaneous analysis of several continental, coastal and marine sedimentary systems (archaeological sequences of shell middens, palaeobeaches, lagoons/sebkhas and oceanic sequences), and on several carbonate supports (speleothems, shells…). We will also discuss several periods of increased detrital activity, seen at archaeological sites, in lagoons, in karst speleothems and in the Arabian Sea, associated with discontinuous aridification stages in eastern Arabia since the Middle Holocene and a probable change in tropical storm frequency.
They are looking for the connections of terrestrial-marine signals, at very high chronological resolution (10-50 years), in order to discuss their spatio-temporal correlations and causalities, responsible for the evolution of plant and animal biomass, and the adaptation strategies of coastal human communities. Based on the resilience model, we intend to explore the process of reorganisation of the eastern Arabian Neolithic communities in terms

of geographic location strategies, economic and technological adaptations, evolution of social structures, and behaviour aimed at avoiding or reducing impacts.

River mouth mobility during the Ist millennium BCE: The case of the Po and the Etruscan city of Spina (Ferrara, Italy)

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During the first millennium BCE, the main mouth of the Po River was located at the central part of the delta in the area of Comacchio (Province of Ferrara). The river mouth formed a promontory with several beach-ridges well preserved and visible on aerial photographs. The fortuitous discovery of the Etruscan site of Spina in the first part of the 20th century in this deltaic context raises many questions about the resilience of the city in this geomorphological configuration. The connections with the Mediterranean basin, the Po Valley and the Alps and Apennines mountains makes it a privileged commercial hub. For several decades, the issue of proximity to the river and the coast has been central to understanding its commercial dynamism but also the risks that may lead to the decline of this short-lived city (6th-3rd century BCE). This ancient deltaic lobe has been little explored regarding the Late Holocene and offers limited dates except for major trends obtained by interpolation. The chronology of the local succession of the ancient coastline is based on tangible archaeological evidence providing a coastline in the archaeological sense and a *terminus ante quem*. However, numerical geochronological tools have never been used to date these deposits. A French-Italian core drilling campaign was conducted as part of a project called “EOS-Etruscan on the Sea” (2020-on) in 2022. This new sedimentary data, based on an innovative sampling strategy with systematic drillings on the paleochannel and the beach-ridges, will be studied by a multiproxy approach combining several dating techniques (^{14}C, OSL, and portable OSL reader) with various sedimentological analyses. We explore, thanks to a high-resolution analysis, the river mouth deposits over time and space, as well as their relationships with the city.

New chronological evidence reveals a continuously inhabited Neolithic–historical settlement in south China

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The Xindian Ancient City (XAC) site is the most complete and frequently excavated urban site in the lower reaches of the Minjiang River. Archaeological and chronological research of this area helps clarify the history of human activity at the site and restore the geographical background of the ethnic minority regimes who lived in the coastal areas of south China during the Eastern Zhou dynasty and the related influence on regional civilisation. Dating results suggest that the site was built during the Spring and Autumn and Warring States periods (3.2–2.4 thousand years ago), which can reasonably explain the presence of relics from the Warring States period on and within the wall. Our dating results are also consistent with the late Neolithic stone tools and pottery fragments found in the area, suggesting that the site was an ideal settlement before castles were constructed. Based on the spatial distribution of the Neolithic sites and Holocene transgression records in the Fuzhou Basin, it was found that coastline advance and retreat were the main factors affecting the paleo-human activity in the Fuzhou Basin during the late Neolithic period. Previous studies showed that the seawater gradually withdrew from the basin around 2 ka BP. Before this, humans mainly lived in the crescent-shaped area on the west side of the Fuzhou Basin, close to the ancient coastline. Based on existing archaeological results and chronological data, it can be shown that the lower reaches of the Minjiang River, where Fujian Province's capital is located, has long been the centre of ancient human activity in the coastal areas of south China, with a civilisation history of 6–4 ka and a city construction history of at least 2.9 ka.

Crovani lake as a natural laboratory to test man-climate-environment interactions in island ecosystems of Mediterranean during the last six millennia

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Islands of the global oceans are experiencing destructive impacts of climate that deeply affect ecosystems stability. This is of particular concern for the large Mediterranean islands, which are considered both hotspots of biodiversity and world's most vulnerable areas to climate change. Understanding the long-term effects of climate and human impact on such island ecosystems is fundamental for the development of any conservation strategy. To this regard the use of palaeoecological research methods has the potential value to identify key periods where human societies and climate changes transformed the island ecosystems in different ways.
Corsica is one of the most interesting places of the Mediterranean to investigate with this approach. This island was crossroad for many populations in the conquest of the Mediterranean and is one of the major plant biodiversity hotspots in Mediterranean. Recent palynological and geoarchaeological investigations opened a new era in the study of this island allowing to refine the knowledge on environmental dynamics and to question former paradigms.
We carried out a multidisciplinary investigation on the sediment cores extracted from the Crovani coastal lake (NW Corsica) in order to define the action of climate, geomorphological processes, and land-use on the landscape changes over the last 6000 years. The results highlight that anthropogenic and climate-induced fires favoured the development of Mediterranean maquis, dominated by *Erica* and *Quercus ilex*, from ca. 6000 to 3350 cal. BP. A change in arboreal vegetation triggered a short but intense sediment input into the pond between ca. 3350 and 3200 cal. BP. This is chronologically consistent with runoff events recorded in several coastal sites of western Corsica, possibly related to a climate change occurred in sites of the western Mediterranean. The evidence of agriculture in pollen record is earlier than any archaeological evidence previously available in this part of Corsica and dates from 3900 cal. BC. Human impact has been responsible for the degradation of the maquis only from approximately 1000 cal. BC, and it intensified during Roman times, when the area experienced the first phase of galena exploitation. Our findings further suggest an influence of solar activity on centennial-scale forest cover variations.

New evidence suggesting human arrival in Mallorca prior to 5000 cal BP

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There is no agreement on the timing of human colonization of the Balearic Islands. Three arrival models consist of: 1) Early (~9000 cal BP) without permanent habitation, 2) Classical (~7500 cal BP), and 3) Late (~5000 cal BP). Although the last two models suggest the existence of stable settlements, only the third one has been deemed plausible. Here, we present archeological and new sea-level data that imply human colonization on Mallorca before 5000 cal BP. Genovesa Cave (also known as Cova de'n Bessó) is located in the eastern part of Mallorca at ~400 m from the coast. It is a typical littoral cave with dry passages and galleries/chambers flooded by the sea-level rise. Genovesa Cave hosts abundant pottery and stone constructions. The latter includes a stone-paved path connecting the cave entrance with the first underground lake, a wall of cyclopean technique parallel to the foregoing path, and a stonewall built by placing large boulders on top of each other without mortar or cement in the entrance lake (~1.5 m deep) to bridge the only two dry chambers in the cave. This walkway, which is 0.5 m high and its top is presently submerged by 1 m, provided access to an inner chamber, where pottery attributed to the Naviform Culture (ca. 3500 cal BP) was discovered. This structure was thought to have been constructed around this time. However, the western Mediterranean deglaciation sea-level curve based on phreatic overgrowths on speleothems from coastal caves of Mallorca, suggests that by 3500 cal BP, the water depth in the lake would have been 1.25 m. Building a bridge that remains 0.75 m underwater is highly improbable. Using the same sea-level curve, we suggest that the bridge was constructed as early as 6000 cal BP (when sea level first encroached this part of the cave), but not later than 5500 cal BP (when the water in the lake was 0.5 m deep). If this scenario is correct, the possibility that stable human settlements existed in Mallorca prior to ~6000 cal BP should be reconsidered.

Burial Dynamics and Abrupt Climate Change at the Shell-Midden Site of Canímar Abajo, Matanzas, Cuba

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Archaeological and paleoclimatic data provide unique insights into societal resilience, adaptation, and transformation in the face of abrupt climate change, but few studies have examined such responses through the lens of prehistoric burial dynamics. The purpose of this paper is to examine the role that abrupt climate change had in influencing the timing of site abandonment and the shaping of cultural practices (e.g., diet, burials) at Canímar Abajo, an extensively studied site on the north-central coast of Cuba. A minimum of 220 individuals have been exhumed from two separate cemeteries at Canímar Abajo, which are stratigraphically separated by a shell midden. Radiocarbon dating of the human remains indicates that the older cemetery dates to at least 3300-2750 cal BP and the younger cemetery to 1590-1000 cal BP. Starch grain and isotopic analysis indicates that these populations depended on marine and terrestrial resources, including cultigens.

A new synthesis of paleoclimate data from Cuba, consisting of high-resolution analyses of speleothems, and pollen, isotopic, and foraminiferal data from lagoons and cenotes, shows that the timing of the older cemetery aligned with the "pan-Caribbean drought," and that its termination at ~2750 cal BP is closely associated with the 2.8 kyr event, an episode of cold SSTs in the North Atlantic and very dry conditions in the Caribbean. The younger cemetery was also associated with a relatively dry climate from ~1600-1000 cal BP, and that the end of its use is coincident with the abrupt onset of humid conditions beginning 1000 cal BP. The data from Canímar Abajo reveal a close correspondence between the termination of the large cemeteries and abrupt and high-magnitude climate changes, suggesting a causal link between the two such that settlement demography was affected by sudden stresses to critical freshwater, terrestrial, or marine resources.

Interdisciplinary research of buried ancient settlements and agricultural fields in Jägala Jõesuu, northern Estonia

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Palaeosoils of buried historical agricultural fields, as well as Stone (ca. 3100 BC) and Bronze Age (ca. 700 BC) settlement sites were studied in northern Estonia using a set of archaeological, palaeobotanical and geoarchaeological methods, including sedimentological and soil geochemical analyses, AMS radiocarbon and luminescence dating, and ground penetrating radar study. The National Geographic Society funded the research. According to radiocarbon dates, this area was used for slash-and-burn agriculture from ca. 2000 BC until ca. 1400 AD. Fields were arranged on top of the mid-Holocene coastal landform system, consisting of seaward□dipping beach deposits and covered by coastal dunes, which developed during the coastal retreat at ca. 5500–5000 BC. Sandy palaeosoils of agricultural fields are characterized by low organic C content, depleted P, Sr and Fe concentrations, and well-developed soil profiles suggesting podzolisation. Palynological and phytolith analyses showed that wheat, barley, rye, millet and perhaps hemp or hops were grown there. Up to 3-m-thick layers of dune sand covering the fields accumulated rather quickly and were probably not related to intensive agricultural land use. According to the combined luminescence age, based on seven datings, this took place around 1524–1581 AD. The development was most likely caused by catastrophic deforestation due to tree felling and/or forest fires, followed by reactivation of old dune sands. It is possible that the complete destruction of forests in the area was the result of the raid or siege of the nearby town and castle of Tallinn by the troops of the Grand Duchy of Moscow during the Livonian War (1558–1583) between 1560 and 1577 AD.

Resilience and Political Ecology of Human-Geological Environment Relationships: the case of Helike, Greece

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Single-event environmental phenomena endure as explanations of widespread social catastrophe across time and space. In particular, earthquakes have been linked in various places throughout the past with large-scale social downturn, most notably at the end of the Late Bronze Age (LBA) (c. 1200 BC) and in the late Roman period (fourth to sixth centuries CE) in the eastern Mediterranean. This paper shows how earthquakes traditionally perceived as 'natural' disasters are not merely 'natural' but social and a critical factor in political ecological relationships. This argument draws from advancements in geoarchaeology and soil micromorphology and soil and architectural material collected and analyzed from Helike, Greece–leader of the Achaean League and infamous victim of the 373 BCE earthquake disaster. The soil micromorphology of seismically triggered soft sediment deformation structures (SSDS) allows for the identification and interpretation of earthquakes and other geological hazards in direct association with settlement architectural remains. The integration of this micromorphological data together with geomorphological, paleoseismological, FTIR, and architectural data from excavations of 16 sites belonging to six occupation phases spanning the third millennium BCE to fifth century CE within the 15 km2 delta plain of Helike shows the interrelations of earthquake deformation and other environmental changes, such as flooding and rapid coastal change, and technological innovation and invention in the human-built environment. Material-geological patterns indicate settlement-wide efforts aimed at resilience–the prevention of social disruption, or disaster–in not only earthquakes but also other environmental hazards, including flooding and rapid coastal change. Changes in the material-geological record from the level of the settlement, to private and public structures, and to particular structural elements indicate distinctive human strategies in resilience through time. The development of resilience in human-geological environment relationships involved decisions that confronted not only immediate geological conditions and change but also negotiations with the constraints of and opportunities afforded by political leadership and organization, economic resources and production, and cultural values and associations, revealing not only resilience, but also more significantly, a political ecology of human-geological environment relationships.

Microfossil investigations as part of multiproxy analyses in ancient harbour sediments – the Roman Harbour of Ephesos versus the Hellenistic Harbour of Elaia

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The complete understanding of human and landscape history and their complex interactions is a highly topical desideratum of modern science in general, and, in particular, of landscape archaeology and geoarchaeology. A variety of specialized scientific disciplines focuses on the investigation of different aspects of past societies and palaeo-environmental changes and conditions. The complexity of the coastline is of crucial importance for the existence of harbours. On the west coast of Turkey, the well protected and deeply incised embayments provided ideal locations for harbours during antiquity. Their connection to the hinterland *via* rivers made these locations even more attractive. However, the enormous fluvial sediment supply led to the siltation of the harbours in relatively short times. Concerning the microfossil inventory, harbours are very similar to lagoons in habitat type and ecology due to their protected position. In harbour basins, eutrophication is common, caused by the input of human waste and the reduced exchange of water. This is reflected by a ubiquitous faunal association, adapted to temporary deficiency in oxygen. Often, the sedimentation rate is higher than in natural lagoons. Silting up of a harbour leads to the separation from the sea followed by a freshening of the water body with a characteristic freshwater fauna during the final phase. This marked change in the faunal composition indicates the disconnection to the sea and the end of the harbour activity. Comparing the Roman Harbour of Ephesos and the Hellenistic Harbour of Elaia the key difference between the two harbour sites are the various sedimentation rates. In Elaia the sedimentation rate was low that caused the present position of the harbour close to the coast, whereas Ephesos was subject of a very high sementation rate causing fast siltation and separation of the Roman Harbour from the sea. Also, stronger sedimentation rates caused stronger human impacts those as dredging, which is reflected in a mixture of microfaunal assemblages.

Session 62: Paleoclimate, paleoweathering, paleoprovenance and machine learning on sediments during Late Quaternary Period

Paleomonsoon variability of the past 2000 years - a high-resolution record from a coastal lake in Southern India

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Extreme weather events are more frequent across the globe. To understand the direction of the changing climatic conditions, the underlying mechanisms need to be addressed. This study aims to reconstruct the paleoclimatic variability of southern India during the past two millennia by adopting a multiproxy approach (geochronology, environmental magnetism, sedimentology, and loss-on-ignition). The study was conducted on a 154 cm long sediment core retrieved from Lake Ramasamudra, Southern India. The multiproxy data spans 1566 years (from 2005 to 439 cal yr BP). The environmental magnetic data reveals the strength of the monsoon in terms of fluctuating magnetic mineral concentration. The magnetic mineralogy of the lake is composed of magnetite (mean S-ratio value = 0.9). The magnetic grains present in the sediments are a mixture of medium to fine-grained, indicating a stronger intensity of pedogenesis in the catchment in response to the enhanced monsoonal conditions. Four distinct climatic phases were identified from the reconstructed paleoclimatic record viz. Phase I: 2005-1550 cal yr BP; Phase II: 1550-1000 cal yr BP; Phase III: 1000-500 cal yr BP, and Phase IV: 500-439 cal yr BP. High values of χ_{lf}, χ_{fd}, χ_{ARM}, and SIRM in phase I suggest a high influx of terrestrial sediments (including fine-grained magnetite), implying stronger monsoon and pedogenesis. A high lake level was also inferred from the low per cent values of sand, as finer particles get deposited far from the shore within the lake, where the hydrodynamic conditions are weak. In phase II, there is a cyclic variability in the concentration-dependent magnetic parameters indicating a strengthening of monsoon, which attains its peak at around 1200 cal yr BP and starts declining to a less humid climatic condition. The monsoonal intensity was the weakest in phase III and shows a further weakening trend indicated by decreasing χ_{lf} value. Phase IV is characterised by low values of concentration-dependent parameters, and high values of sand fraction and organic carbon (OC), suggesting a stronger monsoon. The high values of OC significantly dilute the magnetic properties. Spectral analysis of the χ_{lf} data reveals periodicities of 526, 226, and 67 years, attributed to the solar origin.

Decadal- to centennial-scale periodicities in the Indian summer monsoon in southern India: Evidence from spectral and wavelet analysis of multi-proxy data

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The objective of the present study is to document variations in the Indian summer monsoon and its inherent periodicities during the past 2000 years based on multi-proxy investigations on sediments deposited in Madagadakere (MK) Lake in southern India. For past rainfall reconstruction, proxies like rock magnetics, particle size, diffuse reflectance spectroscopy (DRS), and Fourier-transform infrared spectroscopy (FTIR) have been employed on MK lake sediments. The chronology of the Madagadakere sediment core (MK1) is constrained by seven AMS (Accelerator Mass Spectrometer) ^{14}C dates. The maximum ^{14}C age obtained for the trench samples collected is 2130 ± 30 years with a mean sedimentation rate of 1 mm/year. The down-core variations of rock magnetic parameters ($\chi_{lf,}$ χ_{fd} %, IRM, SIRM, and interparametric ratios), principal component scores of FTIR spectra, as well as second derivative values of DRS spectra, are used to assess the variations in detrital input, pedogenesis, and chemical weathering intensity in the catchment area of the lake.

Based on changes in different proxy parameters, the paleo-rainfall history in the area can be split into four phases..

Phase I (2100–1600 cal. years B.P.): Higher terrigenous influx, strong pedogenesis, and chemical weathering associated with an intensified monsoon were documented, followed by a steady decrease.

Phase II (1600–900 cal. years B.P.): There was a sudden increase in rainfall conditions during the commencement of this phase.

Phase III (900-200 cal. years B.P.): Cyclic variation in rainfall is observed during this period, with alternating dry and wet periods.

Phase IV (200 cal years B.P. to present): An increasing trend of rainfall (resulting in increased detrital influx and strong pedogenesis) towards present is documented during this phase.

Spectral analysis and wavelet of rock magnetic data reveal the presence of periodicities like 296, 72, 60-54, 45, 39-36 years in the palaeorainfall data. The shorter periodicities (60-54, 45, 39-36 years) were predominant during intervals 400-Present, 700-500, 1100-1250, 1800-1400 and not so significant during the intervening periods. Whereas, the longer periodicity of 296 years was predominant throughout the last 2000 years. These periodicities are also observed in other paleoclimatic records from the region, which are ascribed to solar origin.

Paleo-temperature inferred from brGDGTs over the last 18 cal ka BP from Lake Barrine, tropical NE Australia

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Terrestrial temperature exerts a major control on vegetation distribution, the hydrologic cycle and many biogeochemical cycles. Yet little research into terrestrial paleotemperature reconstruction has been conducted covering the Holocene in northern Australia and recent global surface temperature reconstructions include no data from northern Australia. Branched glycerol dialkyl glycerol tetraethers (brGDGTs) are increasingly used to reconstruct terrestrial temperature because of their ubiquity and a preservation window of at least tens of millions of years. Here, we fill this spatial gap through reconstructing mean annual surface water temperature in Lake Barrine in tropical NE Australia from 18.3 to 1.7 cal ka BP using separated 5- and 6-methyl brGDGTs. A 7.2 m master core from the centre of the lake was extracted, along with 5 surface lake sediment samples and 7 soil samples in the catchment area. The result showed that the fractional abundances of all brGDGTs in the catchment soils, surface and downcore sediment in Lake Barrine were closely correlated, with dominant tetramethylated brGDGTs, especially Ia. We applied a global calibration to reconstruct the temperature using lake sediment samples and a binary mixing model to correct the temperature bias caused by different portions of soil-derived brGDGT input. The corrected temperature record compares favourably with independent temperature records from a broader region, with lower temperatures than modern in the late Glacial and higher ones than modern in the early to mid-Holocene.

Luminescence chronology of loess-palaeosol deposits in the Central Shandong Mountains region: Provenances and paleoclimate implications

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The loess-palaeosol deposits of the Central Shandong Mountains (CSM) to the east of the Chinese Loess Plateau (CLP) potentially provide valuable archives for the reconstruction of East Asian monsoon patterns. However, compared to the abundant attention given to the loess layer, fewer studies have explored the palaeosols documentingthe processes and characteristics of interglacial climate changes. The high-resolution chronologies and provenances of the palaeosol in the CSM area are still unclear. In this work, the luminescence ages and paleoclimate proxies in the Shaozhuang (SZ) and Focun (FC) sections were studied, by combining detrital zircons U–Pb ages from the loess-palaesosol in Jingbian, Licheng, Focun, Pianguan and Dongming Yellow River sediments. Quartz single-aliquot regenerative dose protocol (SAR) and K-feldspar post-infrared IRSL (pIRIR290) dating results were obtained in the SZ (8.0 ± 1.1 ka − 50.8 ± 2.7 ka) and FC (3.8 ± 0.3 ka—144.0 ± 7.8 ka) sections to develop the most detailed CSM region chronologies to date. The analyzed grain sizes and detrital zircon U–Pb ages suggest that the provenance of the CSM loess was dominated by local Yellow River sediments. The palaeosols observed in the ffeld in these two sections were composed of both aggradation soils deposited in the interglacial period and non-aggradation soil formed by the weathering and leaching of the underlying loess. We found evidences for the presence of non-aggradation soils as indicated the relatively high 5–16 μm particle percentages, relatively low chemical index of alteration (CIA) values and the percentages of >63 μm particles compared to those of the overlying palaeosol layers. Nevertheless, the loess-palaeosol deposits in the CSM are still the product of the East Asian monsoon and global climatic variations, as the deposits have recorded the glacial-interglacial cycles.

Geochemical and Clay Mineralogy Characterization of Ganga Flood Plain Sediments: Insights to Weathering and Sediment Provenance

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Ganga Flood Plain is one of the most fertile land in the world. The Ganga Flood Plain receives sediments from the Himalayas and the Peninsular region through the Himalayan and Peninsular Rivers. Few smaller rivers (Gomati and its tributaries) which originate in the plainer region of the Ganga Basin carry sediments from older flood plain and converge with the major trunk rivers, the Ganga and the Yamuna. During the monsoon season, Gomati and its tributaries receive surface water from different parts the flood plain in the form of surface runoff. Hence, these rivers play a crucial role in sediment recycling and elemental redistribution. In this study, the sediment samples from cliff sections of the southern Central Ganga Plain along the Ganga, Yamuna and Loni Rivers have been studied for clay mineralogy and major elements geochemistry to evaluate the chemical weathering, elemental characteristic and climatic impact in the Ganga plain. The clay mineralogy data suggests that sediment from the Himalaya region is dominated by illite and chlorite, and the peninsular river sediments are dominated by smectite. In Yamuna River, smectite, chlorite and illite are observed in decreasing order. Whereas, the plain fed river sediments show illite and chlorite. The absence of smectite in the plain fed river sediments suggest that there is negligible sediment contribution from peninsular region. The major element geochemical data suggests that the CaO and Na_2O are relatively less mobilized from the Plainer River sediments suggesting low chemical alteration compared to the Yamuna River and Ganga Rivers due to aridity and low fluid replenishment in the plainer region.

Vegetation dynamics and hydroclimate variability since the LGM from the core monsoon zone of India

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Palaeopalynological study of 2.25 m long, lacustrine sedimentary profile from the Koriya District of Chhattisgarh State, core of the monsoon zone (CMZ), central India revealed that between ~22,200 and 18,658 cal yr BP, open vegetation occupied the landscape under a cool and dry climate, probably indicating a reduced monsoon precipitation. This cool and dry climate, influenced by weakening of the Indian Summer Monsoon (ISM), globally matches with the Last Glacial Maximum (LGM). Between ~18,658 and 7340 cal yr BP, under the influence of a warm and moderately humid climate with increased monsoon precipitation, the open vegetation was succeeded by open,mixed tropical deciduous forest. This open,mixed tropical deciduous forest continued to grow in the region, with an increase in the frequency of some of the tree taxa especially, between ~7340 and 1961cal yr BP under a warm and relatively more humid climate with increased monsoon precipitation, correlatable with the Holocene Climatic Optimum (HCO)/Holocene Thermal Maximum (HTM). Between ~1961 cal yr BP and the Present, dense, mixed tropical deciduous forest came into existence under a warm and relatively more humid climate with further increase in monsoon precipitation. The present study provides an unprecedented record of the vegetation dynamics, climate change and the ISM rainfall variability since the LGM from one of the poorly understood areas of the tropics where rainfall is essentially controlled by the monsoon variability.

Session 63: Late Quaternary fluvial archives from the time of Homo sapiens: Stratigraphical, sedimentological, palaeontological and georchaeological records

Role of the paleo-Yamuna River in riverscape evolution in northwest India during Late Quaternary and its non-contemporaneity to Harappan Civilization

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The avulsion of major rivers has often been linked to the decline and abandonment of the Bronze Age Indus (Harappan) urban centers (~4.6–3.9 ka BP) in northwest (NW) India. It has been documented that a large river system, the Ghaggar-Hakra system, used to drain parts of NW India until the Early Holocene and was fed by two major tributaries, paleo-Yamuna from the east and paleo-Sutlej from the west. Recent work has demonstrated that the paleo-Sutlej was defunct shortly after ~8 ka. However, the role of avulsion of the paleo-Yamuna has remained unresolved because of very limited and fragmented subsurface stratigraphic and chronological data. This work presents high-resolution chrono-stratigraphic data well-supported by 47 optically stimulated luminescence (OSL) ages from six sediment drill cores (~50 m deep) raised across a series of paleochannel traces of the Yamuna in the Haryana, NW India. Our detailed sedimentological analysis shows multi-storied channel sand bodies separated by muddy intervals typical of repeated avulsions and compensational filling in a fan setting. This study exclusively suggests that the avulsion of the paleo-Yamuna River occurred ~18 ka ago. This implies that the Ghaggar-Hakra system draining this region was already weakened during the post-LGM period, and the avulsion of the paleo-Sutlej at ~8 ka resulted in its final abandonment. Since both these avulsions occurred significantly earlier than the expansion and decline of the Indus Civilization in this region, it reaffirms the non-contemporaneity of the Harappan civilization with a large river system draining this region.

Post-LGM fluvial archives and human activity in the NE piedmont of the Pennines

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Study of the post-glacial evolution of the piedmont reach of the River Ure–Ouse in North Yorkshire, UK, reveals a drainage system that is incised into the landscape, in part re-excavating the MIS 2 infill of a pre-existing valley. This incision is manifest in the profusion of gorges and terraced reaches characteristic of this and other eastern Pennine rivers such as the Wharfe, Swale, Wear and Tyne (and also in the deeply incised minor valleys known as 'denes' that drain to the North Sea coast). A similarity between all these systems is that the glaciated landscape into which they are incised is typically ~30 m above their modern channels, while evidence for terrace ages range, from highest to lowest, from Lateglacial to Late Holocene (post-Medieval). The Ure sequence is one of the best developed and best dated amongst such archives. Evidence for human occupation of the eastern Pennines during the latest Pleistocene and the first half of the Holocene is uncommon and tends to be on the uplands; in the valleys themselves such evidence is perhaps largely buried by later sediments. There is abundant activity evident from the Late Neolithic, however, extending from the effects of early agriculture to the construction of henge monuments. Later prehistoric archaeology is plentiful, especially on the interfluve between the Ure and its northern neighbour, the Swale, although there is considerable indication of Iron Age to Romano-British occupation of the valley floors. On the lowest terraces the abundant Medieval archaeology includes remains from shoemaking at Ripon. In addition to a terrace staircase declining from the deglaciation level (+ ~30 m) to the modern river, the fluvial archives include cut-off channels filled to levels comparable with terrace sediments of similar age.

Developments in mapping, dating and quantitative reconstruction of Lower Rhine river activity in the last 3000 years (Niederrhein and upper Rhine delta; Netherlands and Germany)

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The river Rhine grades from valley to delta plain in the Dutch-German borderlands: an apex bifurcation situation that established and evolved in the Late Holocene, in prehistoric and historic times. This densely populated, long and heavily man-used region has been intensively studied from quaternary geological, geomorphological, archeological and historical viewpoints. New findings append and upgrade the state of mapping and dating of morphological features such as alluvial ridges and oxbow channels. Such resolves details of regional landscape genesis and evolution and allows to identify human occupation of the river banks along contemporary channels and their interaction with activity of the river. Maintaining geographical overview and interdisciplinary collaborative networks is essential to keep track and course in this situation of rapidly growing availability of barge loads of diverse and detailed geological-geomorphological, geoarchaeological and paleoenvironmental mixed bags of information.

Critically, the state of research reached in the last decades has allowed for quantitative reconstruction of the activity of the Lower Rhine river: insight in the pacing of meander migration (i.e. paleo-morphodynamics), insight in the heights that extreme floodwaters occasionally reached and the peak-discharges associated with those (i.e. paleo-hydraulics). In turn, that information feeds into actual issues. One of these is flood safety, where the information feeds in to work on recurrence times of large floods, besides on human landscape alteration effects vs. historic climate variability vs. Anthropocene present and near-future conditions. Another one is heritage management through multiple time frames: e.g. connected to UNESCO world heritage status of *Limes* roman empire military border sites, to interest in the Dark Ages, to interest in High-Late Medieval urbanization, to medieval embankment, to 18th century early river engineering.
The contribution will provide a condensed overview of the new insights, focusing on the Dutch-German Rhine river borderlands, citing regional reports and recent international publications.

The relative importance of geomorphic processes and anthropogenic activities in the organic carbon storage of temperate floodplains

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River systems convey organic carbon and mineral sediment through the landscape, but also store a significant proportion in their floodplains for varying amounts of time. A proper quantification of the floodplain storage component is required to gain insight in the land-ocean transfers and cascades of organic carbon and mineral sediment at Holocene timescales. In this study, the Holocene floodplain carbon and sediment storage was quantified for five medium-sized rivers in contrasting environments. The study sites consist of a mountain river (Upper Dee, Scotland), lowland rivers in the European sand belt (Grote Nete and Zwarte Beek, Belgium) and loess belt (Dijle and Mombeek, Belgium).

The Holocene stratigraphy was reconstructed using 1246 soil corings across 131 river valley cross-sections. Combining these reconstructions with radiocarbon dates and measured sediment properties allowed to quantify the total sediment and carbon storage. The results indicate that in the high-energy river system of the Upper Dee, the total storage of mineral sediment and organic carbon is largely dependent on the local geomorphology, with the local storage being largely determined by the river dynamics. In contrast, the observed differences in floodplain storage in the studied lowland river basins is strongly linked to the history of human impact in the region. Sediment storage is on average 4.4 times higher in the loess belt river catchments compared to those in the sand belt. Similar differences, although less pronounced, can be observed for the storage of organic carbon, with floodplains in the loess belt containing 2.6 times more organic carbon than floodplains in the sand belt. This difference can be attributed to the inherent erosion sensitivity of loess soils and an opening of the landscape and increased hillslope erosion since the Bronze Age. This resulted in the deposition of large amounts of mineral sediment in the river floodplains. As a result, the alluvial peat layers were buried and protected from oxidation and human activity. As such, the Holocene trajectory of river floodplains, determined by the interplay of geomorphic and anthropogenic factors determines the current floodplain stock and its potential for future storage.

Multi-proxy palaeoenvironmental reconstruction of two fluvial systems in the United Arab Emirates and implications for human dispersal

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Rivers are important terrestrial archives to reconstruct the palaeoenvironment. The investigation of rivers in dryland environments is challenging due to the sporadic and high variable precipitation, triggering fluvial activation which often occurs as high energy events. However, they are important additions to other proxies like speleothems, lake sediments or phytoliths indicating wet periods, to reconstruct environmental change and climate. The study region in the northern United Arab Emirates located at the edge of the largest sandy desert on earth, the Rub' al Khali, is sensitive to climate change and experienced pronounced shifts between wet and dry periods in the past. Today the climate of the region is influenced by the mid-latitude Westerlies, the Indian Ocean Summer Monsoon as well as tropical cyclones and lies north of the current summer position of the ITCZ. Although both investigated ephemeral river systems of Wadi Dhaid and Wadi Iddayyah are directly adjacent to each other and both originate in the Hajar Mountains, they show different characteristics of source material and river morphology. In this regard, they find different ways to adjust their course to reach a maximum flow efficiency and an equilibrium form. The sedimentary structures identified, range from scour-and-fill structures, cross-stratification, planar bedding to structureless sediments and inform on different flow conditions through a comparison with sedimentary investigations of modern rivers, other palaeorivers and flume experiments. In addition, Wadi Dhaid and Wadi Iddayyah are further explored using remote sensing and by the construction of longitudinal profiles. The dating by optically stimulated luminescence (OSL) and radiocarbon of different stratified sections along the course of the rivers allow together with sedimentological and geochemical investigations to reconstruct the environmental change over the last 160 ka in the region. Over this time scale different phases of increased erosion and deposition are recognised. Moreover, it is shown that fluvial activity occurred partly contemporaneous with aeolian deposition and was almost continuously. Finally, the palaeonevironment investigations are linked to the debate about human dispersal in which Southeast Arabia is recognised as a key region.

The Mid to Late Pleistocene Atbara River basin in eastern Sudan as a habitat for hominins

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The Atbara River, as the northernmost major tributary of the Nile and connecting the Ethiopian Highlands to the Nile, may have played an important role in the question whether the Nile functioned as a faunal and cultural dispersal route or as an ecological refuge during the Pleistocene. About 50 m of alluvial deposits, exposed over more than 200 km along the middle Atbara in eastern Sudan, document the river history and the environmental conditions in this region for the last ~250 ka, according to our new age dating. The sediments contain abundant fossils, including hominins, and stone tools. The sedimentary succession, divided in a previous study into two major sedimentary units, the Butana Bridge Synthem (BBS) and the Khashm El Girba Synthem (KGS), each with three sub-units separated by erosive unconformities, consists of river channel deposits and floodplain sediments with intercalated paleosols. The units differ in the grain size of the channel sediments, in width-to-depth ratios and vertical and lateral connectivity of channel elements, the ratio of channel to floodplain deposits, the internal architecture and sedimentary structures in the channel sediments, and the type of paleosols.

Gravel-dominated deposits of wide-but-shallow channels with intercalated floodplain sediments in the oldest unit (BBS; ~250 to ~160 ka) represent poorly confined braided channels with highly variable but sometimes high runoff. Overlying floodplain sediments contain Calcisols and Acheulean stone tools; apparently the floodplains were visited by hominins. Sandy-gravelly channel sediments with lateral accretion deposits in unit KGS1 (~160 to ~130 ka) represent deposits of meandering rivers. Near a point bar, hominins produced abundant Acheulean tools. Skeletal finds also show that hominins inhabited the area. The mostly sandy channel sediments of unit KGS 2 (~130 to ~60 ka) with high width-to-depth ratios and frequent lateral accretion deposits intercalated in thick floodplain deposits including Vertisols indicate well-confined meandering channels, with the internal channel architecture suggesting a pronounced seasonal or intermittent discharge. In unit KGS3 (~30 to ~15 ka), laterally and vertically amalgamated sandy-gravel channel deposits represent deposits of shallow, poorly confined braided channels. The paleoclimatic and tectonic controls on the depositional processes will be discussed.

Holocene dynamics of fluvial systems in the Moulouya basin (Morocco) : questioning the role of climate changes in river morphogenesis

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The dynamics of fluvial systems and their responses to different forcing during the Holocene are still poorly documented in North Africa. In the Moulouya basin, the main Mediterranean catchment in Morocco and one of the largest in the Mediterranean, pioneering studies had already suggested the role of climatic control and revealed the potential of the alluvial archives of its upstream basins.

This strong potential led us to develop a comparative and systemic approach to the Holocene evolution of the alluvial plains in two sub-basins of the Moulouya. With this regional approach, coupled with high-resolution multiproxy analyses and numerous radiocarbon dates, this work confirms the potential for palaeoenvironmental reconstruction of the alluvial archives and allows us to build a robust morphosedimentary and palaeoenvironmental framework for the Holocene of the upstream basins of the Moulouya and northeast Morocco.

This work also reveals the predominant role of climatic forcing, on multi-millennial to centennial scales, on the dynamics of Holocene fluvial systems in the Moulouya basin. Two morphosedimentary units (MSU) of regional extent, characterized by a strong homogeneity of the hydrosedimentary and morphogenic dynamics, have been highlighted. A fluvio-palustrine formation (MSU 1, 10800 - ~6000/5000 cal. BP) appears strongly controlled by the orbital variations of the last African Humid Period. This formation was then eroded during a period of hydrogeomorphological instability associated with strong fluvial activity (8200 - 6200 cal. BP). A new multi-millennial period of aggradation (MSU 2, 5200 - ~2000/1000 cal. BP) marks the lasting transition to a hydrological regime characterised by intermittent flow and strong flood dynamics, linked to the progressive aridification experienced by North Africa and the southern Mediterranean during the Late Holocene.

On a millennial to centennial scale, this work also highlights the sensitivity of the Moulouya alluvial archives to rapid climatic changes (RCCs) during the Holocene, e.g. two phases of major incision followed by strong fluvial activity reflecting the responses of the hydrosystems to the 8.2 and 7.6-7.3 ka RCCs. Finally, this work suggests that solar forcing could have acted as a factor of morphogenesis in the upstream basins of the Moulouya.

Changes in the Magnitude and Frequency of Holocene Monsoon Floods on the Mahi River, Western India

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During the past seven decades, the monsoon-dominated Mahi River of western India has experienced extraordinarily large magnitude floods that rank among the highest recorded rainfall-runoff discharges per drainage area in the world. The large magnitude floods on this river are a direct outcomes of severe tropical cyclones implanted within the Indian summer monsoon. The cluster of extreme floods in the past few decades represents an inconsistent strengthening in both the magnitude and frequency of large floods when compared with the 17 ka record of palaeoflood deposits in the basin. Scour line, shrub line, trimlines resulted from erosion of largest(s) floods on the channel margins of the river and its tributaries have served as palaeostage indicators of the recent floods. An investigation of relative magnitude for modern, historical and palaeofloods shows that the present and last century is characterized by very large magnitude floods. The study demonstrates that most of the historical floods and palaeofloods, for which there is some evidence, were smaller in magnitude than the modern floods. The examination further reveals that the floods are clustered in distinct time intervals. There is evidence of clustering in five different periods - (a) 9000 - 7000 BCE, (b) 3000 - 0 BCE, (c) between 1520s - 1720s, (d) Around 1920s, and (e) between 1960s - 1990s. The largest floods between 1960s and 2020s modern record of the Mahi River at the Wanakbori site is 120 yr flood and its tributary the Som River at Rangeli site is 720 yr flood in a probability distribution. A comparison between palaeofloods and gaged record demonstrating the enormous recent increase in the magnitude and frequency of severe floods. This cluster of severe floods of current and last century could reflect changes in either climate or land use or construction of dams. These post-1950 CE floods are thus the largest at least in the Holocene. Numerous palaeoflood studies in tropical-storm regions reveal a similar increase in high-magnitude floods within the past seven decades, suggesting a widespread climatic cause for this pattern.

Session 64: Mapping Ancient Africa: Climate, Vegetation & Humans

When the desert was a lake: Providing context for Homo sapiens development in the northern Kalahari

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The Okavango rift zone and delta, and the Makgadikgadi paleo-megalake form a dynamic system in northern Kalahari, where tectonic activity, climate change, sedimentation, and biota have interacted in a complex pattern. Paleogenomics and regional climate modeling studies recently suggested that the region may have been a hotspot for *Homo sapiens* evolution.

Here we present results from the first scientific deep drilling project (OKAMAK) in the northern Kalahari, Botswana. Two drill cores, OKA (230 meters) and MAK (210 m), were drilled in the Okavango delta and Makgadikgadi paleolake, respectively. Cores recovered shallow and deep-water sands, muds and evaporitic lithologies of the Cenozoic Kalahari Group extending across the unconformity into the pre-Cenozoic Karoo Group sandstones.

Focusing on the Quaternary, we discuss stratigraphy and initial multiproxy data, developing chronologies and interpreting the complex climate of the region, history of river piracy, evolution of the delta and infilling phases of Makgadikgadi and assess the international collaborative potential of this yet to be fully understood region.

Paleolakes and socioecological implications of glacial "greening" of the South African interior

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Determining the timing and drivers of Pleistocene hydrological change in the interior of South Africa is critical for testing hypotheses regarding the presence, dynamics and resilience of human populations. Combining a suite of new OSL ages and radiocarbon dates with hydrological modelling, we demonstrate the presence of several late Pleistocene palaeolakes and infer regional-scale invigoration of hydrological networks in the South African interior during Marine Isotope Stage (MIS) 3 – particularly 55-39 ka and 34-31 ka – and during MIS 2. The climatic changes required to sustain these hydrological systems would likely have resulted in the replacement of xeric shrubland by more productive higher grass cover vegetation, capable of supporting increased ungulate diversity and biomass. Some support for the latter is found in the existing fauna records. A well-known feature of many of these interior landscapes is the abundance of Middle and Later Stone Age lithic (surface) assemblages. Together these observations contribute to a growing recognition that that Pleistocene interior of South Africa provides an important counterpoint to coastal archaeological and palaeoenvironmental records, and must be considered in wider understandings of climate and human population dynamics through the Pleistocene.

Evaluating refugia in recent human evolution in Africa

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Homo sapiens have adapted to an incredible diversity of habitats around the globe. This capacity to adapt to different landscapes is clearly expressed within Africa, with Late Pleistocene Homo sapiens populations occupying savannahs, woodlands, coastlines and mountainous terrain. As the only area of the world where Homo sapiens have clearly persisted through multiple glacial-interglacial cycles, Africa is the only continent where classic refugia models can be formulated and tested to examine and describe changing patterns of past distributions and human phylogeographies. The potential role of refugia has frequently been acknowledged in the Late Pleistocene palaeoanthropological literature, yet explicit identification of potential refugia has been limited by the patchy nature of palaeoenvironmental and archaeological records, and the low temporal resolution of climate or ecological models. Here, we apply potential climatic thresholds on human habitation, rooted in ethnographic studies, in combination with high-resolution model datasets for precipitation and biome distributions to identify persistent refugia spanning the Late Pleistocene (130–10 ka).We present two alternate models suggesting that between 27% and 66% of Africa may have provided refugia to Late Pleistocene human populations, and examine variability in precipitation, biome and ecotone distributions within these refugial zones.

Homo sapiens behaviour and adaptation in East Africa. New evidence from an open-air site in a modern Ethiopian savannah environment: the GOT10 site.

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The preservation of *in situ* open-air archaeological contexts is often rare, especially for arid landscapes. In East Africa erosion caused by environmental phenomena is one of the principal events that make difficult the preservation of organic and, sometimes, inorganic remains. Moreover, these phenomena may affect the conservation of archaeological stratigraphies making extremely hard the analysis of human occupations. For this reason, when found, organic remains in arid eroded landscapes represent an extremely important proxy for the reconstruction of past human behaviour and occupation dynamics. However, it is still difficult to combine the data with the lack of a secure stratigraphic archive to compare with. The site named GOT10, in the Gotera area, southern Ethiopia, shows a stratigraphic deposit located in a depression of modern savannah environment rich in artefact and faunal remains in primary deposition in association with fireplaces, dated to MIS 3 (ca. 45-42 ka, AMS). The analysis of the GOT10 archaeozoological record - one of the few open-air sites that have faunal remains fairly conserved in the savannah environment - is fundamental to include Ethiopia in the broader debate about site functionality and seasonality, mobility, and environmental exploitation during the late Pleistocene. The faunal remains from GOT10 site come both from the stratigraphic layers (2018 and 2022 fieldwork) and from the collection of surface material (2017, 2018, and 2022 fieldwork) within the Gotera area. Despite the difficult conservation of the faunal remains due to the weathering and the surface contexts, the state of preservation of these materials is good. We propose the case study of GOT10 faunal assemblage for the reconstruction of past human occupation dynamics in a problematic context characterized by both deposits in situ and surface eroded materials.

Pan-African Climate and Vegetation over the Quaternary and Implications for Human Distribution

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We have constructed a climate-vegetation dataset that spans the Quaternary period using the HadCM3B-C coupled climate model and the BIOME5 vegetation model. We use this to explore the key mechanisms that determined Pan-African precipitation and vegetation change over the Quaternary which we reconcile against observations. We focus on the interconnection of precession-induced North/South variability that constitutes the North African Humid Periods, and East/West precipitation variability which has been hypothesised to be driven by changes in the tropical Walker circulation. We identify the impact from the three key forcings: orbital variations, greenhouse gases, and the ice sheets, and explore how these change through the Quaternary. In addition, based on information on how climate affects hunter-gatherer population densities in modern ethnographic data, we use our climate-vegetation-model data to simulate changes in distribution and abundance of humans in Africa between 400 and 10 ka. Assuming that climate was the main driver of human distribution in the Pleistocene, we explore the idea that there could have been number of core population areas across Africa that have been variously interconnected depending on the prevailing climate conditions.

Middle Pleistocene Vegetation dynamics at Yiapan, a high elevation extra-basinal Site complex: Significance to human behavioral adaptations

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Yiapan is a high-elevation mid-Pleistocene site complex dated between ca. 500ka and 60ka. Sedimentary units observed here indicate that the site was near a large water body. At the same time, lithic artifacts point to several technological phases found in multiple successive layers of occupation. The lowest layer is composed of large cutting tools of the late Acheulean period, the middle and upper layers are characterized by smaller tools consistent with hafting (tools with handles) and the use of obsidian sourced from non-local sources. This toolkit shift signals an important behavioral adaptation and cognition that increases as early modern humans emerge. The toolkit choice is often associated with availability/access of raw materials. Prolonged occupations such as the one depicted at Yiapan the suggests stability and accessibility of valuable resources. In this paper, we seek to determine habitats associated with site occupation between ca. 500ka and ca. 400ka during Acheulean phase, which are attributed to archaic Homo sapiens.

We present archaeological and paleobotanical data collected from two occupational layers identified in the stratigraphy profile

Phytolith data from the lower occupational layer is dominated by a mixture of woody- and grass- derived morphotypes. Palms and sedge phytoliths coupled with fresh water diatoms are significantly present in specific levels. This suggests terrestrial landscapes covered with wooded grasslands vegetation type. Fresh water habitats were also present on the landscape that could either be swamps/wetlands or lake, consistent with the preliminary geological data. In the upper layer, woody-derived morphotypes decreases with increased grass phytoliths suggesting reduced canopy habitats associated with MSA toolkit.

Currently, we have zero zooarchaeological data that could shed light on faunal community in the basin. It is not yet clear whether this was just a raw material sourcing- and tool making-site or it is due to taphonomic challenges that did not favor bone preservation at the site. However, this is work in progress, and we hope to get faunal data that can enrich the current palaeobotanical data to accurately determine the kind of ecosystem that is associated with the technological shift noted at the site.

An astronomical age model for Lake Bosumtwi (Ghana) to reconstruct West African climate and environmental change in the last million years

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Lake Bosumtwi evolved in a 1.07 Ma meteorite crater in Ghana. Due to its climatic and environmental sensitivity in the tension field between the North African Monsoon (humid, wet) and the Harmattan (dry and dusty winds from the Sahara), this limnic archive has been intensively studied. Drilling in 2004, supported by the International Continental Scientific Drilling Program (ICDP), recovered core samples from the complete sedimentary archive. Yet, detailed climatic and environmental reconstructions for the time prior to the last glacial cycle have not been completed, mostly due to the absence of a robust age model. In 2022, we obtained core scanning natural gamma ray data of the ~300 m lacustrine sedimentary sequence. Based on this data, we are generating an astronomical age model that can be directly compared to the independently-dated section of the Holocene and Upper Pleistocene, but extends farther back in time. Our age model will provide critical chronologic context for the numerous existing and new proxy data that illuminate past changes in climate, environment, and ecosystems. This breakthrough will considerably expand our knowledge about the environmental conditions in the cradle of humankind beyond the last glacial cycle.

Late Holocene vegetation and climate of Wonderwerk Cave, South Africa, from charcoal

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The Wonderwerk Cave represents one of the rare cave sites in the arid interior of southern Africa that preserve multiple palaeoclimate indicators, such as pollen, charcoal, and phytoliths. Despite the large amount of charcoal excavated from the Holocene strata, pollen has been the most used indicator for Holocene environmental conditions. Pollen is less spatially precise compared to charcoal, hence this study is aimed to reconstruct the palaeoclimate of the area around the Wonderwerk Cave during the late Holocene by studying charcoal from one of the Late Holocene strata, Stratum 2b, which records the time between 2.3- 0.5 ka cal BP. The second aim of this study is to infer the human-plant interactions that were happening at that time. To do this, a sample of 50 charcoal fragments was studied, the wood they originate from identified, and climate and human-plant interactions inferred from the woody species identified. The sample was found to be dominated by shrubs or small trees that can tolerate dry environmental conditions, such as *Ozoroa paniculosa, Searsia lancea, Brachylaena huillensis, Commiphora sp., Maytenus undata, Olea europaea* subsp. *africana* and *Ziziphus mucronata.* This indicates that the environment was mostly dry. However, the presence of taxa that tolerate wetter environments such as *Heteropyxis natalensis, Olinia ventosa,* and *Berchemia discolor* suggests that rainfall patterns may have been variable. The presence of taxa that commonly grow near river banks suggests that there may have been a water source nearby, similar to Boesmansgat found 15 km from the cave. Overall, the results indicate a semi-arid climate and an open bushveld with a grassy layer, and small woody plants that enabled the humans occupying the Wonderwerk Cave to harvest wood, fruits, and medicine from them.

Palaeoenvironments of the Cape Floristic Region: New research & current developments

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The Cape Floristic Region (CFR) is a key focus area within southern Africa due to its botanical importance in terms of high levels of biodiversity as well as its rich cultural and archaeological heritage. The area is highly sensitive to cycles of regional and global environmental change, and records obtained from the region provide valuable information regarding past climate variability. Prior to the last decade, few high resolution palaeoenvironmental records were recovered from the region, and its environmental history remains relatively poorly understood. This presentation summarises the research initiatives currently being undertaken by Nelson Mandela University's Palaeoecology Laboratory. This ongoing work aims to provide a comprehensive understanding of climate, biodiversity and human-environment interactions within the CFR, with a particular focus on the understudied eastern subregions.

The records presented are derived from unique natural archives found within the CFR including rock hyrax middens and coastal lowland wetland deposits. These archives are being analysed within a multi-proxy, multidisciplinary framework, using pollen, fungal spores, micro- and macrocharcoal, diatoms and geochemistry to elucidate changes in vegetation, herbivory, fire, hydrology and climate.

This work is designed to actively develop regional capacity, using the new Palaeolab and engage students and early career scientists from the area to contribute to the development of fundamental knowledge regarding their environment and history.

Late Holocene palaeoecological studies at Lake St Lucia, KwaZulu-Natal

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Palynological studies were done on lacustrine sediments deposited during the last ~7000 yrs. BP in Mkhuze Swamp, which drains into the most northern part of Lake St Lucia located in the Indian Ocean Coastal Belt Biome of KwaZulu-Natal, eastern South Africa. The aim was to reconstruct the past vegetation and to infer past climate fluctuations as well as human disturbances to complement growing evidence from other disciplines about these questions in the area. Palynological results shows a dominance of *Podocarpus* (yellowwood tree), other forest elements, marine indicators as well as Chenopodiaceae/Amaranthaceae accompanied by a decline in fungal spores between 7000yrs BP and 3500yrs BP indicating a mesic forested environment with marine influence leading to an increase of the water table along the coast. Regionally, pollen records in Lake Eteza shows similar vegetation change during that period. A peak of Fungal spores and grasses with a corresponding decline in *Podocarpus* and other forest elements and the disappearance of marine elements between 3500yrs BP and 2300yrs BP, signals a drop in water table probably due to evaporation, which was due to an increase in temperature. During the last 1000yrs pollen of *Podocarpus* decreased and a peak of pollen of the woodland tree S*pirostachys* (tamboti), together with strong Chenopodiaceae/Amaranthaceae presence and the appearance of marine elements (scolecodonts and foramenifera linings) suggest a change from a forested environment to an open woodland vegetation and an increase in the salinity of the swamp. Similar pollen fluctuations are found in Lake Eteza and Sibaya. The presence of *Pinus* pollen at the top of the profile suggests the onset of European settlement which were introducing pines for timber production. Regional pollen records in the last ~7000 cal. BP shows a general trend from a mesic forested environment towards an open woodland environment.

Holocene palaeoecological reconstructions of landscape dynamics at the year-round/winter rainfall boundary in the Cape Floristic Region (Southwestern South Africa)

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The Cape Floristic Region (CFR) extends over the SW corner of South Africa, encompassing landscapes that fall under the year-round and winter rainfall areas. Alterations of the present-day rainfall seasonality patterns are expected under projected scenarios of climate change. This accentuates the need to address several fundamental issues regarding the ecological present and future of the highly biodiverse heathlands and shrublands of the CFR. In particular, the drivers of internal biome dynamics and the controlling factors regulating the boundaries of the different biomes (namely the Fynbos and Succulent Karoo).

Here we present the results of a multi-site palaeoecological experiment designed to test the impact of long-term seasonality changes on fynbos-succulent karoo boundaries at the boundary between the winter and year-round rainfall areas of South Africa. Our results show a clear relationship between rainfall seasonality and vegetation dynamics in a high-elevation site, whereas at lower altitudes other factors such as local runoff, ground-water supply and underlying geology seem to be more explanatory of the vegetation at local scales. These transitions can be explained from differential responses of taxa to experimental manipulations of summer rainfall.

High-resolution sedimentary charcoal records of fire link burning, vegetation change, climate, and pastoralism in the Cape Floristic Region, South Africa

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Fire is central to the Cape Floristic Region (CFR)'s highly biodiverse and disturbance-adapted Fynbos Biome. However, prehistoric fire regimes and their ecological consequences remain poorly understood. Here, we use high-resolution sedimentary charcoal records to interrogate links between fire, climate, vegetation, and pastoralism in the Fynbos. We reconstruct fire activity using charcoal particles from two coastal, ecotone lakes – Eilandvlei, a Fynbos-Afrotemperate Forest site experiencing year-round rainfall, and Verlorenvlei, a Fynbos-Succulent Karoo site experiencing winter rainfall. Both records provide exceptionally high continuous-resolution data from 4200 cal BP to the present, spanning the arrival of pastoralism into the CFR ~2,000 years ago. Both records are sufficiently high-resolution to interrogate human impacts on fire, with approximately 2-year time steps at Eilandvlei and 10-year time steps at Verlorenvlei. At Eilandvlei, our preliminary results, spanning the period 4250 to 2200 cal BP, show the highest charcoal influx occurs from 4250 to 3500 cal BP, co-occurring with more frequent, higher magnitude fires and 16-25 years between burns. A significant decline in fire activity occurred around 3400 cal BP, after which fire frequency slowed to 33-66 years between events. At Verlorenvlei, results span 4250 to 3350 cal BP and show charcoal influx, peak magnitudes, and fire frequency are considerably lower and less frequent, with fire activity peaking around 3600 cal BP with 40 years between burns. Fire-vegetation links at Eilandvlei suggest that as fire activity decreased into the late Holocene, fire-adverse Afrotemperate Forest vegetation thrived at the expense of Fynbos. Our data suggest Fynbos fire regimes are more dynamic than indicated by historical observations, and points to the importance of using high-resolution fire histories to understand how climate and human impacts shaped disturbance in the CFR over centuries. Both reconstructions are ongoing and being generated in tandem with experimental burning of known vegetation to establish biome-specific charcoal morphotype and morphometric keys and a near-surface, sub-annual fire history calibration study.

Reconstructing the fire history and palaeoenvironment at Thyspunt, southern Cape coast, South Africa.

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With climate change and ecosystem degradation at their peak, there is a conscious need to understand both phenomena. This is to better create mitigation, adaptation, and management strategies not only from a global perspective but also from a regional and local one. The southern Cape coastal region forming part of the Great Cape Floristic Region in South Africa is an example of an area with rich biodiversity and ecological history that needs to be explored further. This is to establish ecological baselines for the region and to better inform conservation and management strategies. Palaeoenvironmental studies can play a crucial role in the management and conservation of biodiversity and landscapes. A more comprehensive look at the palaeoenvironments of the Eastern Cape as a subregion of the Cape Floristic Region through fire reconstruction and sediment analysis is necessary. The need for fire reconstructions from the southern Cape coast is because the dominant vegetation (fynbos) is fire-dependent, and thus vegetation changes are shaped by fire. The fire regimes for this study have been reconstructed using sedimentary micro- and macrocharcoal from a sediment core (TP-1) extracted from Langfonteinvlei wetland at Thyspunt, covering the last 5000 years. The sedimentary characterisation is based on loss on ignition and geochemical analyses which provide better insight into the geological and geomorphic setting, climate history, and sediment properties of the area. The preliminary results from the geochemical data indicate high calcium carbonate composition throughout the sequence followed by very high organic content encompassing the last 500 years. The geochemical data also indicate that the sediments are associated with shallow marine and near-shore depositional environments with a sharp increase in clay content at about 4500 cal yr BP representing a low-energy environment. There are prominent macrocharcoal peaks around 4000 and 200 cal yr BP, with the former peak most likely associated with an increase in wildfires (driven by climate change) and the latter possibly reflecting human influence at that time.

Key terms: Palaeoenvironment, fire reconstruction, southern Cape coast, micro- and macrocharcoal, sediment analysis.

Floristic clues to the origins of the Dahomey Gap from the Ewe-Adakplame forest (Benin, West Africa)

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The Dahomey Gap, a 200 km wide dry corridor separating the West and Central African rain forest blocks is still largely discussed as an important biogeographic phenomenon. Understanding its origin and evolutionary is a fundamental pre-requisite for an effective conservation and management of the vascular plant species hosted by the remaining forest relics and its related biodiversity. Here, we explore the degree to which the Dahomey Gap has formed a barrier between the diverse forest relics to the west and east and we present the floristic similarity between target forest patches from Ghana, Benin and Nigeria. We anticipate that the grassland dominance of the Dahomey Gap is the more persistent state for the region through the Quaternary and therefore that the current forest patch is a 'relic' from a relatively recent (Holocene) and short-lived (few thousand years) connection between the more ancient diverse forests to the west and east. The dataset contains 376 Species ranked in 267 Genera and 74 Families that are heritage plant species belonging to the Regional Centre of Guineo-Congolian Endemism. Jacquard similarity index at Species level, showed the highest values 0.093 within Nigeria and 0.071 (Benin and Ghana). This trend is confirmed at Genera and Family level showing that the forest relics appear to be floristically similar. Interestingly, our analyses suggest that the Dahomey Gap should not be considered as a strong phytogeographical boundary within the West African forest belt. But rather a consequence of combined effects from past climatic and anthropogenic disturbances. These results are consistent with other studies who placed the floristic boundary of the Upper Guinea further at the Cross River area, eastern part of Nigeria. Then, we can consider that floristic diversity is an important palaeoenvironment reconstruction marker. Also, palaeoecological studies combining Fires and Vegetation are needed to assess human impact on this landscape since the development of an autonomous African metallurgy.

Filling the calibration gap: the importance of modern pollen studies from dry and transitional regions in Africa, and a case study from North-East Namibia

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Modern pollen-vegetation relationships are crucial for calibrating our understanding of past ecosystem dynamics as inferred from palaeoecological records. By understanding how vegetation responded to factors such as climate and anthropogenic changes in the past, we can make informed decisions about managing ecosystems for future generations. In Africa, these questions are particularly important as climate change impacts ecosystem dynamics, and changing human activities alter traditional management regimes. It has been demonstrated that modern pollen data from dry and transitional regions in Africa are severely lacking, and efforts are needed to set up monitoring over multiple years in these areas in order to inform palaeoecological reconstructions.

In this study, we present modern pollen trap data from Bwabwata National Park (BNP) in North-East Namibia. BNP is located within the Kavango-Zambezi Transfrontier Conservation Area and is the only national park in Namibia which allows people to live within its boundaries, in multiple use areas. BNP lies within the Sudano-Zambezian floristic region, at the southern extent of the broad leaved tree-shrub savannah biome and experiences a semi-arid climate. The area is currently of particular interest due to oil prospecting, with considerable debate around environmental impacts happening in Namibia on this topic. It is therefore very important to understand long term vegetation dynamics in the region; there are some palaeoecological records but no calibration studies from the area. In this study we use modern pollen data in conjunction with remotely sensed estimates of vegetation cover to calibrate pollen-vegetation relationships. This can then be applied to palaeoecological records from the region to improve our understanding of vegetation change over time.

This pilot study presenting 1 year of pollen data lays the foundations for setting up a network of long-term pollen monitoring plots in Namibia across a range of ecosystems. This will enable us to better understand how vegetation responds to climate and management changes in dry and transitional African ecosystems.

Investigating the potential of high-resolution carbon isotopes in archaeological Protea and Podocarpus charcoal as a rainfall seasonality proxy

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Tracking changes in rainfall seasonality is difficult using the materials preserved in the archaeological record. Today, South Africa is uniquely positioned at the interface of both the Indian and Atlantic Oceans and the tropical and temperate climate systems. This produces a distinctive seasonal rainfall gradient that extends over the country: a Summer Rainfall Zone (SRZ) to the east, a Winter Rainfall Zone (WRZ) to the west, and the Year-Round Rainfall Zone (YRZ) occupying the southern coast and interior between them. While existing proxy records have helped elucidate broad shifts in these zones over time and space, high-resolution fluctuations in seasonal rainfall are limited and often qualitatively inferred. This study thus explores an alternative approach to quantitatively reconstruct rainfall seasonality from a ubiquitous yet largely underutilised material: archaeological charcoal. We first investigated whether an established seasonal precipitation proxy showing success in both modern and fossil Northern Hemisphere evergreens can be applied to South African evergreen (*Protea* and *Podocarpus*) wood and charcoal across rainfall zones. Using these results as modern analogues, the proxy was then tested on archaeological *Proteaceae* and *Podocarpaceae* charcoal from the Last Glacial Maximum and late Pleistocene. Successive carbon isotope measurements across the growth axes of the modern wood and charcoal samples produce seasonal amplitudes comparable to local climate data, though with some slight offset. This was hypothesised to result from subsampling resolution effects and/or some input of dry season moisture and/or, in the case of the charcoals, depletion in carbon isotope values with carbonisation. Nevertheless, the ratios of summer to winter rainfall calculated for the modern wood and charcoal samples show that the proxy has significant potential to differentiate between seasonal rainfall regimes. These preliminary results demonstrate the potential of using archaeological charcoals to quantify past seasonal rainfall and, in turn, apprehend the nature of climatic shifts over glacial-interglacial cycles, of importance to late Pleistocene human habitation and cultural trends.

Session 66: Data modelling and Inference

Session 67: Exceptional archives: Leveraging visible and non-visible lagerstätten with cutting-edge methods to broaden our knowledge of Quaternary ecosystems

Session 68: Rivers and fans: sediment and landform archives of long-term Quaternary landscape development and environmental change

Session 69: Quaternary palaeolandscape, palaeoclimatic and palaeoenvironmental change in the North Sea

Session 70: Global and local views on the ecological, environmental, and climatic backdrop for hominin dispersal out of Africa in the early Pleistocene

Session 71: Quaternary of North Africa: chronostratigraphy and paleoclimatic variations

Session 72: The role of Tephrochronology in the study of Earth system dynamics during the Quaternary: Event timings, duration and frequencies

Session 73: Altered landscapes (Pleistocene and Holocene) of the archaeological sites

Session 74: Advances and new challenges in modeling landscape change in the “Anthropocene”: Transdisciplinary approaches using remote sensing and geoarchaeology

Session 77: Quantitative proxies for paleoenvironmental reconstructions from loess and terrestrial archives

Session 78: Subduction zone palaeoseismology

Session 79: The Global Tropics from the Pliocene to the Anthropocene

Long-term change in the lowland forests of the Yasuní National Park, western Amazon

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Uncertainty remains regarding the origin of the high biodiversity found within lowland forests of the Amazon Basin, particularly with regards to legacy impacts of human populations, natural disturbance and ecosystem stability. Current research is challenging the idea of Amazonian forests as untarnished, mature ecosystems, suggesting instead that a more complex patchwork of forests exists in varying stages of recovery from previous perturbations. Uncovering the source, duration and extent of past disturbance is key to understanding modern patterns of biodiversity and is vital to inform vegetation and climate modeling, and direct conservation. The Yasuní National Park, located in northeastern Ecuador, holds some of the highest levels of plant and animal diversity on the planet and is also home to several indigenous groups. Despite the ecological and cultural importance of Yasuní, few palaeoecological studies exist within the region. Here we present the pollen and charcoal analyses of a record taken from a *Mauritia flexuosa* palm swamp spanning the last 3400 years. While rainforest elements were constant throughout the record, a replacement of the dominant taxa *Iriartea* by *Mauritia* as well as the rise in Araceae and *Euterpe* occurred over the last 1500 years. We interpret this change as a transition from seasonally flooded forest to a palm swamp and suggest it was driven by shifts in local hydrology. The importance of local hydrology is further highlighted when comparing results with a nearby 6000 year old sedimentary record that exhibits a similar transition from floodplain forest to palm swamp. These cores document late Holocene forest history and river migration or flooding, which in addition to the ecological consequences, could have influenced patterns of human occupation, as human presence is evidenced in local archaeological works nearby.

Human ancestors dispersal : the role of climate changes in Africa during late Pliocene

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At the end of the Pliocene, before the triggering of the Greenland ice sheet, while CO_2 was around 400 ppm, we explore the potential dispersal of *Australopithecus* via the Genus' fossil record and climate and ecological niche modeling. In Africa, tropical areas experienced drastic hydrological changes that were mainly driven by precession cycles, which deeply modulate monsoon intensity and patterns. An illustration of such hydrological variability is the evolution of Mega Lake Chad. To explore to what degree strong climate modifications occurring over tropical Africa could have modified hominin dispersal, we simulated the response of climate, vegetation, and hydrological cycles of the mid to late Pliocene (4–3 Ma) to astronomical forcing. We provide a series of Earth System models (IPSLCM5A2) associated with high resolution simulations using only the atmospheric component, coupled with a dynamical vegetation model (ORCHIDEE), both of which were used to estimate ecological niches with a spatial resolution of 50km.
Our results indicate that:
1. Four regions appear as suitable habitats for hominins. Three of them correspond to regions with a documented fossil record: East Africa, the Chad lake basin, and South Africa, whereas, in the fourth, Northern Africa, no hominin fossils have yet been documented for this period.
2. Some regions remain suitable to hominins during full orbital cycles and, therefore, may be qualified as refugia, especially the Turkana region in Eastern Africa and Southern Africa.
3. A corridor between South and East Africa is not always available for dispersal. In contrast, there is a continuity between East Africa and the Lake Chad Basin.
This study pinpoints the important role of the tropics in climate changes over Africa.
We will present the strength and limitations of such approaches, which were made possible through a large trans-disciplinary effort between paleontologists, paleoenvironmentalists, paleoclimatologists, and niche modelers.

Modelling malaria spread in the Late Pleistocene

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Malaria is a major widespread disease that led to the rise of resistance mutations in the human genome (e.g. sickle-cell disease) and its worldwide incidence is strongly driven by factors contributing to the Anthropocene, particularly in the tropics. These include increasing human population density and urbanisation, with significant impact from environmental factors. For example, changes in environment due to anthropogenic land use and land cover modifications influence the choice of the *Anopheles* vector's breeding location (varying species prevalence, survival, adaptation and proliferation), feeding habits (zoophilic-to-anthropophilic shift) as well as the climate, an important factor for vector's spatial distribution range. Individual sibling complex show different relationships with climatic factors, which affect the development of both the parasite and the mosquito. All these aspects may favour an increase of malaria transmission, yet mutations in the human genome indicate that selection pressures pre-date urbanisation, and originate in an allegedly environmentally "pristine" past.
This paper investigates the possible impact of anthropogenic alterations of the environment on malaria incidence around 25-22 thousand years ago (KYA)/in the late Pleistocene in West and Central Africa. It considers whether human behaviour created the conditions for the *Anopheles* vector species to thrive and, therefore, shaped and catalysed the spread of malaria.
We model the distribution of three vectors (*An. gambiae, An. funestus and An. coluzzii*) and their sibling groups, examining environmental and climate changes and signatures of human activity. This project combines several aspects to model the interactions between the environment, malaria vector and human factors. It brings together paleoclimate and environmental data, epidemiological information, vector and human distribution data, as well as human intervention on the environment, ultimately testing whether a "Deep Anthropocene" in the tropics has shaped a major global health burden.

Uncovering human-megafauna interactions in the drowned caves of the Yucatan Peninsula, Mexico.

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The Yucatan Peninsula is a massive, kilometres-thick carbonate platform situated in southeastern Mexico. Drainage systems in the area produce a flat topography where no surface rivers flow. Karstification and surface permeability have led to the formation of one of the most extensive active underground cave systems in the world. During the Last Glacial Maximum the peninsula was higher and the sea level more than 100 m lower than today, meaning that many of these caves were dry and accessible until the middle Holocene. Cold and dry climate conditions prevailed during the LGM and beyond, with a significant reduction of forest biomes occurring at 13000 - 8000 cal BP. From 8,000 years ago, warmer and wetter conditions, alongside a rise in sea level, resulted in cave submergence and an expansion of the present-day tropical and sub-tropical vegetation of the region. Given its record of human presence throughout this period, the sites of this region present the possibility to explore the varying impacts of climatic change and human presence on different megafaunal populations. These caves have been documented as providing well-preserved paleontological records in submerged, secure contexts. Nevertheless, there has been limited taphonomic and scientific work undertaken on these remains. Here we present the preliminary results of a multidisciplinary analysis of megafaunal remains uncovered from the drowned caves of the Yucatan Peninsula. We have applied taphonomy (including cutmark analysis and site formation studies), radiocarbon dating, palaeoproteomics, and stable isotope analysis to megafaunal remains from the caves in the Cenote Iza, Cenote Papakal, Cenote Ziizha, Cenote Izah, Cenote San Antonio, Taj Mahal cave, Cenote Sifa and, Cenote Las Palmas to assess the interactions between our species and megafauna in this region and to build up more detailed records of megafaunal chronology and ecology in a little-studied portion of the Americas. Contextual and geochronology framework for these remains supports the hypothesis that the cave systems in the peninsula were accessible for much of the last glacial period, serving as natural traps for animals and people.

Land-use changes and human-environment interactions in the Maya Lowlands of Belize during the post-Classic and colonial periods

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The ancient Maya of tropical Mesoamerica are amongst the best-studied cultures across the globe, including research focused on socio-environmental dynamics. Several regional palaeoclimate records from speleothems and lake sediments indicate drought and hydroclimatic instability during the spatio-temporally heterogenous Terminal Classic Decline (TCD) ~750–1100 CE, when monumental construction at many Classic Maya sites ceased. Following the TCD, many populations appear to have shifted to coastal or inland locations with direct access to water. While the Classic Maya are known to have managed scarce surface water resources across this limestone-dominated region to support their cultivation of maize, squash, beans and sweet potato, they also tended and exploited forest and savanna resources including palms and pines for food, construction materials and fuel. How the Maya adapted their land-use strategies in the post-Classic, especially in areas where the archaeological record suggests continuity of habitation, has received little attention. Additionally, in the Belizean portion of the Maya Lowlands, palaeo-data have rarely been used to examine socio-environmental dynamics during subsequent phases of Spanish and British colonialism. During these periods, local economies were driven by extraction and export of forest resources such as logwood, mahogany and chicle, followed in the twentieth century by diversification to include bananas, citrus and sugarcane. Here, we present the first pollen and macrocharcoal records from the Belize River Valley, from a sediment core from Laguna Castillo, a small oxbow of the Mopan River near to the Classic Maya temple and ceremonial centre of Cahal Pech. From these data, and new palaeolimnological and archaeological data, we infer local land-use changes from the Maya post-Classic through the Spanish and British colonial periods. We compare these results with coeval data from the New River Lagoon in northern Belize, location of the Classic Maya temple site of Lamanai which also shows continuity of habitation after the TCD.

An 8,500 year record of vegetation change, climate, and human impacts from Baie des Baradères, Haiti, using pollen analysis and XRF core scanning

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The Insular Caribbean is a region sensitive to multiple climate stressors, including hurricanes, droughts, and sea-level changes. Such is the case for Haiti, a country located in the circum-Caribbean region, that has also been affected by extensive anthropogenic land use, rendering much of its landscape devoid of vegetation, and increasing its vulnerability to erosion and floods. Despite this, there is limited long-term environmental data from Haiti to provide critical baseline data to assess modern-day and future environmental risk.

To address this, pollen identification and analysis was undertaken from a sediment core collected from Baie des Baradères, a shallow bay adjacent to the delta of the Baradères river, to reconstruct vegetation and climate changes, as well as human impacts, in the area during the last 8,500 years. We also used high-resolution XRF core scanning to document the sedimentary context of the core and distinguish between inputs of terrestrial and marine-derived materials. The chronology of the core was established with over 25 AMS dates.

The results show that at the base of the core (from 8,500 to ~4,000 cal yr BP), mangroves and other coastal plants were dominant, whereas they decrease in abundance towards the core top, possibly representing sea level rise and a migration of the coastline farther from the core site. An abrupt increase in elemental titanium occurs in at least seven portions of the core beginning about 2,500 cal yr BP, and may represent an influx terrestrially-derived sediments into the bay from the nearby Baradères river. While our results are still preliminary, these events may be associated with precipitation from hurricane impacts, and the pollen from these sections is associated with high levels of Asteraceae and ferns, reflecting disturbance to the local landscape. Finally, large quantities of fern spores and herb pollen such as Asteraceae, Amaranthaceae, and *Borreria* are dominant in the upper sediments of the core, and likely reflect extensive human-impacts on the Haitian landscape over the last few hundred years. This project represents one of the few pollen records available from Haiti, and helps fill a large spatial gap in such records from the insular Caribbean.

One million years of tropical vegetation and fire from a biological and climate hotspot

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The Lake Towuti Drilling Project (Sulawesi, Indonesia) is located in the Indo Pacific Warm Pool, home to the world's warmest oceanic waters and a globally important driver of climate. Sulawesi is also part of Wallacea and a place of enormous biological diversity.

Through the drilling project, we have developed parallel records of palaeovegtation for the last million years using pollen, charcoal, ancient chloroplast DNA (cp aDNA) and compound specific stable isotope analyses of leaf waxes ($\delta 13C_{wax}$).

The early part of record reflects the rifting that took place one million years ago and the evolution of a swampy valley bottom to the deep lake that is modern day Lake Towuti. Importantly it shows a constantly forested landscape with compositional changes appearing to follow orbitally driven changes on glacial interglacial timescales and linked to fire.

Major findings include:

- Forest covered lowland Sulawesi over last one million years.
- Compositional shifts driven by glacial scale climate change and fire.
- Fire is present throughout the record, although most abundant from 60 ka to 12 ka.
- Dipterocarps disappear with an increase in fire at 60 ka
- Implications for understanding their biogeography in the region
- Forest reorganisation and lake level proxies suggest driest conditions from 40 ka to 12 ka.
- 31 ka to 17 ka appears not only drier but more seasonal – contraction of montane gymnosperms.
- The last 45,000 years stands out as different to anything in the preceding ~950 ka.

Food production drove environmental and demographic changes over the Holocene in Western Africa

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There are strong inferred demographic patterns associated with changes in food-production and environment over the last 5000 years in western Africa. Neither food production strategy nor environment alone are enough to explain past demographics for the entirety of the Holocene. Only when multiple proxies are examined can we tease out the complex human-environment relationships of the past and the shifting locus of anthropogenic activity. Land-use is an often-overlooked aspect of human-environment interactions, which can have significant impacts on both demography and land cover. While the cyclical nature of human-environment relationships can make discussions of causality complex, land use is a critical element to understanding how past societies have left landscape legacies that are still relevant to Earth system's today.

In West and Central Africa, an area with some of the world's most threatened tropical forests, the degree to which climate or humans drove major past changes in vegetation, have been debated. Many scholars have seen humans as opportunistic agents, rapidly moving into areas that were good for farming and avoiding the supposed 'barriers' of rainforests until they were naturally reduced by mid-Holocene climate change. On the other hand, it has been proposed that humans were the cause of major changes in rainforest extent and distribution, including the Late Holocene Rainforest Crisis (LHRC), in parts of West and Central Africa. While the cause is most likely to be some combination of extreme weather events and land-use, the impacts being debated had knock on effects for the continental carbon cycle, soil erosion, vegetation and climate as well as major population movements and the spread of farming to the rest of Africa.

Here, we present a Per Capita Land-Use (PCLU) approach that models the interconnected nature of demographic trends and socio-environmental systems over the long-term in West and Central Africa. We focus on two different but interconnected dynamics: 1) changes in human demography relative to changes in both food-production and climate, and 2) the potential environmental impact of these observed land-use and demographic trends.

Session 80: Magnetostratigraphy and Environmental Magnetism contribution to understand paleoclimatic and paleoenvironmental changes

The use of paleomagnetism as a dating and correlation tool of Quaternary sequences: strengths and limitations

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The Earth's magnetic field variations due to geodynamo processes inside the liquid outer core span time scales of geologic interest, extending from centuries (e.g., paleosecular variation – PSV), millennia (e.g., geomagnetic excursions and polarity reversals), tens of thousands years (relative paleointensity stratigraphic trends - RPI), up to tens of millions years (changes in the frequency of occurrence of geomagnetic field reversals). These variations are recorded and preserved in sedimentary and volcanic rocks. In the past decades, the chronology of peculiar geomagnetic features that occurred during the Quaternary has been defined in an increasing detail, allowing the definition of a "Geomagnetic Instability Time Scale" (GITS) now extending to the last 2.8 million years and thus providing an original tool for dating and correlating Quaternary stratigraphic sequences at high resolution.

Though the mechanisms of acquisition and preservation of a natural remanent magnetization in rocks can be complex and are presently only partly understood (especially for sediments), the reliability of the paleomagnetic signal can be checked and tested through a series of independent rock magnetic and stratigraphic methods.

In this talk, I will discuss some case studies illustrating strength and limitations of paleomagnetism to the development of Quaternary stratigraphy. In particular:

- The use of PSV and RPI stratigraphic records for dating and correlating sedimentary sequences in polar regions (where other classic proxies for dating and correlating sequences may be poorly represented or even totally absent), spanning the last tens to hundreds thousands years;
- The effects of a variable lock-in depth and diagenetic processes in sediments and their implications for achieving high-resolution paleomagnetic dating and correlation;
- The characters and consistency of paleomagnetic records preserving details of fast and wide geomagnetic variations such as geomagnetic excursions and full polarity reversals, with a particular emphasis on the Matuyama-Brunhes reversal, which is the most recent and well documented full reversal of the Earth's magnetic field and has an outstanding importance for the definition of a Quaternary Time Scale.

Paleomagnetic and 10Be records across the Pleistocene and Pliocene geomagnetic polarity transitions from the Boso Peninsula, central Japan

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The geomagnetic polarity reversals have occurred repeatedly in the geological eras, and are recorded in sediments and lavas almost contemporaneously, providing significant stratigraphic markers to constrain ages of strata and correlate strata in remote areas. However, complex structures of the geomagnetic polarity reversals and the process by which sediments acquire remanence would make age offset between remote sites. Therefore, reconstructing past geomagnetic polarity reversals is significant not only for elucidating the mechanism of the reversal, but also improving the age constraint of sediments. Here, we provide preliminary paleomagnetic records with ^{10}Be data which is a proxy of the geomagnetic field intensity across the lower and upper Mammoth transitions (late Pliocene), and lower Jaramillo transition (early Pleistocene) from on-land marine successions in the Boso Peninsula, central Japan. These transitions are known to have occurred during periods warmer than the preindustrial and thus are significant stratigraphic marks for paleoclimatic and paleoceanographic studies. Structures of the geomagnetic polarity transitions will be discussed by comparison to the paleomagnetic and ^{10}Be records across the Matuyama–Brunhes transition in the Chibanian GSSP site.

Can Optically-Stimulated Luminescence (OSL) Techniques Detect Reductions in Geomagnetic Field Intensity? A Case Study from Lake Suigetsu, Japan, across the Laschamp Excursion

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The most recent polarity reversal of Earth's magnetic field, the 'Laschamp Excursion', occurred ~41,000 years ago, with an accompanying dramatic weakening of the magnetic field intensity during the preceding and subsequent transitions in to and out of the reversal itself. Records of 10Be (principally, the Greenland ice-cores) and 14C (including tree-ring data series), both cosmogenic nuclides, demonstrate increased production rates at this time when the weakened geomagnetic field allowed greater penetration of solar and cosmic radiation into Earth's upper atmosphere. It follows that increased extra-terrestrial radiation receipt would also reach the Earth's surface, and Cooper et al. (2021; Science 371, 811–818) recently postulated that such effects could have resulted in "major environmental changes, extinction events, and transformations in the archaeological record".

In the present study, we investigate whether such an increase in ground-level radiation receipt is detectable in terrestrial sediment records using optically-stimulated luminescence (OSL) techniques. To this end, we utilise the varved sedimentary profile extracted from Lake Suigetsu, central Japan, a truly world-leading archive of palaeoclimatic and palaeoenvironmental change. We present contiguous Portable OSL (POSL) measurements (n = 235) spanning ~45,000 to 35,000 cal BP, and compare these with the published high (21 year) resolution palaeomagnetic dataset from Suigetsu produced by Hyodo et al. (2022; Communications Earth & Environment 3, 79).

Supporting palynological, µXRF, and thin-section microscopy data from Suigetsu support climatic and/or environmental correlations with our POSL dataset, with minerogenic properties controlling the luminescence signal. The most marked single event identified within our dataset relates to a major earthquake ~39,200 cal BP, which resulted in re-routing of inflow to the lake. A superimposed relationship between the luminescence profile and geomagnetic intensity remains tantilising, and we shall focus on this discussion in the conference presentation.

Indian Summer Monsoon variability during the Late-Holocene in southern India: Evidence from lacustrine sediments

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Geological archives like lake sediments can provide direct evidence of the past variability of rainfall on a local or regional scale, with a relatively high temporal resolution. In the present study, environmental magnetic (magnetic susceptibility) and Fourier Transform Infrared (FTIR) spectroscopic analyses were performed on sediment samples of Cheppandikere lake (CK), southern India to decipher palaeorainfall variations in the region. The 56.5 cm long sediment core is constrained by 4 AMS ^{14}C dates. The magnetic susceptibility data indicates the fluctuations in the rainfall during the past 1700 years. Some of the mineral components identified using FTIR spectroscopic analysis include quartz, orthoclase, microcline, kaolinite, montmorillonite, hematite, calcite and organic carbon. Principal Component Analysis was carried out on FTIR data from which, three components (PC1, PC2 and PC3) are identified. The variations in the PC1 scores may reflect the changes in terrigenous influx to the lake, which in turn is dependent upon monsoon. PC2 scores are interpreted to be authigenic factor and PC3 is interpreted to be aridity factor. Both rock magnetic and FTIR data indicates the presence of three climatic phases during the Late Holocene period. the period ~1700 - 1250 cal. years B.P. is characterized by high rainfall. During ~1250 to 833 cal. year B.P., moderate rainfall is documented. Whereas, and period ~833 cal. Year B.P. to present are characterized by decreasing trend.

Late Miocene sedimentary chronology and paleoclimate significance of the Jianzha Basin in the northeastern margin of the Tibetan Plateau

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Jianzha Basin is located in the northeastern part of the Tibetan Plateau and contains a thick sequence of Cenozoic sediments which are crucial for investigating the growth of the Tibetan Plateau and the record of the evolution of the Asian inland arid environment. Magnetostratigraphic results show that Late Cenozoic sedimentary sequence from the Jianzha Basin has recorded a continuous geomagnetic polarity sequence from C5r.3r to C3r, the section spans the interval from 11.8-5.8 Ma in the Late Miocene. Based on the high precision paleomagnetic dating framework and frequency susceptibility index (χ_{fd}), the cycle stratigraphy of Jianzha Basin was studied, whose results show the χ_{fd} of the deposit sediment displays a significant periodic change at around 7.2 Ma, which the record reveals that the East Asian summer monsoon (EASM) is dominated by 41 ka obliquity period before ~7.2 Ma and controlled by 100 ka short eccentricity period after 7.2 Ma. Spectral analysis of oxygen isotope records of benthic foraminifera from the South China Sea shows strong short eccentricity period and weak obliquity period between ~5.8 and ~7.2 Ma, and strong obliquity period and weak short eccentricity period between ~7.2 and ~11.8 Ma, which is consistent with the spectral analysis of frequency susceptibility (χ_{fd}) from the Jianzha Basin. In addition, it is found that the EASM climatic transition from 100,000-year orbital period to 40,000-year obliquity period occurred around 7.2 Ma, which is similar to the climatic transition around 0.9 Ma in the Middle Pleistocene. Therefore, the climate change result will provide a new similar model for predicting future monsoon climate changes. This study was supported by the National Natural Science Foundation of China (Grants 42272221, 41772167); and supported by projects funded by the Second Tibetan Plateau Scientific Expedition (STEP) program (2019QZKK0704); and supported by the Central University Research Foundation, Chang'an University (Grants 300102272901).

Session 82: Data science and paleoecology: current intersections and advances

Applying statistical thinking to palaeo data through generalized additive models

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Palaeoecological and palaeoenvironmental stratigraphic data exhibit a number of features that make them complex to analyse; for example they i) are autocorrelated in time (and, potentially, also in space), ii) are generally irregularly spaced in time, and iii) have complex variance properties due to time averaging and sampling processes.

This complexity has some unfortunate consequences. All too often, data are not subject to any form of statistical analysis, and, when they are, often that analysis uses inappropriate statistical methods. Furthermore, analysts will often invent their own ad hoc approaches to get answers to their specific questions. The statistical properties of such ad hoc approaches are rarely known, however.

A number statistical methods have been developed over recent years and decades that can handle the complex needs of palaeo data. Among these methods is the generalized additive model (GAM) and related extensions. The use of GAMs to model temporal trends in palaeo data has increased steadily in recent years, thanks, in part, to the availability of high quality, open source software like the R package mgcv. GAMs are relatively simple models that will be familiar to anyone who has taken a graduate course in ecological statistics, and yet GAMs are incredibly versatile models that can be adapted to suit many pressing questions that palaeo scientists wish to address.

In this talk I will briefly introduce GAMs and show how penalised splines, which underpin the GAM, work, before moving on to cover some recent developments from my own work that extend GAMs to new areas and questions. In particular, I will discuss; i) models that go beyond the mean to investigate trends in other moments, such as variances of palaeo time series, ii) using derivatives of splines fitted in a GAM as estimates of rates of change in palaeo time series, and iii) copula GAMs that can estimate how the correlation between two variables itself changes over time. In each case I present a relevant motivating example and supplement the talk with fully worked examples in R that are available on GitHub.

Understanding the drivers of vegetation change in the Southern Rocky Mountains with paleobotanical records and a forest landscape model

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The lower montane ecotone of the Rocky Mountains in western North America is a mosaic of forest, woodland, shrubland, and grassland where trees exist near their limits in drought tolerance. Widespread tree mortality during recent droughts and local limitations in regeneration following wildfire may presage extensive conversion of forests to shrublands and grasslands in a warmer and drier future. However, understanding of the temporal dynamics among climate, disturbance, and vegetation is limited by a paucity of paleoecological records from unglaciated lower montane ecosystems. Furthermore, historical records and inventory plots provide a short window to evaluate models capable of projecting vegetation change. We are addressing these challenges by combining new pollen, macrofossil, charcoal, and oxygen isotope data from Blue Lake, Colorado USA (2540 m a.s.l.) with simulations from the LANDIS-II forest landscape model. Our modeling approach tests competing hypotheses that account for past vegetation change to understand long-term interactions among climate, disturbance, and vegetation on a scale that is relevant to ecosystem management. Sediment began accumulating at Blue Lake following a landslide ca. 9000 cal yr BP. Pollen data indicate that mixed coniferous forests with abundant pine (up to 50%) grew near Blue Lake during the middle Holocene. Macrofossils demonstrate the local presence of *Pinus ponderosa*, a species presently limited to riparian settings ~400 m lower in elevation that does not form extensive stands in the interior of the Rocky Mountains today. *Pinus* declined after 6000 cal yr BP, contributing 10 – 20% of the terrestrial pollen sum after 4000 cal yr BP, when increasing Poaceae and *Artemisia* pollen indicate a more open environment with forest patches of *Pseudotsuga* and *Picea.* A contemporaneous decrease in calcite $\delta^{18}O$ may indicate the declining abundance of summer rain. LANDIS-II simulations of vegetation surrounding Blue Lake suggest warmer summers with more abundant summer precipitation supported stands of *Pinus ponderosa* in a mixed coniferous forest before 6000 cal yr BP. Our combined paleoecological/modeling approach implies that future summer moisture availability and the strength of the North American Monsoon will be important determinants of the resiliency of forests in the lower montane ecotone of the Rocky Mountains.

Automatic recognition of pollen and spores in (sub)fossil pollen samples

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Manual pollen analysis is labour-intensive and expensive. Hence, attempts to automate pollen analysis have a long history, yet only appear feasible with the advent of modern deep learning techniques. Recent studies report progress in the automated classification, i.e. the identification of prepared pollen grain images.

As one step further, we explore automated pollen and spore analysis in true samples from lake sediments. Such approach requires not only classification but also the detection of pollen grains in the sample matrix. We therefore use a 2-stage artificial neural network model: The first stage, a Faster R-CNN object detector, is trained to detect the location of pollen grains in the sample matrix without further classification. The second stage, a MobileNetV3 image classifier, uses higher resolution image crops to identify those pollen grains located in the first stage.

The algorithm has been trained using ~20,000 manually labelled pollen slide images with about 20,000 labelled pollen grains and non-pollen objects. The images have been scanned as z-stacks with at least 5 focus layers. Our image classifier uses the best focus layers for pollen identification. Tests proof that our approach is well able to locate pollen grains (step 1) while success of identification (step 2) differs among pollen types. Recall and precision are promisingly high (>90%) for the pollen types most abundant in the training data, yet is still poorer for rarer pollen types. We illustrated to usefulness of the approach in two examples. The first is a specialized application, aiming to determine masting years of beech in an annually resolved, 300 year pollen record from Western Poland. In the second example we use automatic pollen counts to refine an existing pollen record from NE-Germany to 1-cm resolution. Based on these result we discuss suitability of our approach to complement manual pollen counts.

Establishing FAIR Data Resources as Key Elements in Data Science Approaches

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Charles Babbage – one of the founders of modern computing, along with Ada Lovelace – was asked ‘Pray, Mr. Babbage, if you put into the machine wrong figures, will the right answers come out?’ This question highlights an essential and persistent challenge for data science: ensuring transparency of scientific workflows and analyses. Data Science approaches often depend on large volumes of data as inputs, and may involve “black-box” numerical approaches for analysis. Given the data volume and workflow complexity, understanding the underlying data, and the workflows employed within these models is critical for understanding the ultimate output and their interpretive limits. The community-wide push towards FAIR scientific approaches are broadly intended to enhance both data accessibility and transparency, through the specific goals of Findability, Accessibility, Interoperability and Re-Use (Wilkinson et al., 2016).

Paleodata resources, such as the Neotoma Paleoecology Database, the Paleobiology Database, LinkedEarth and the PaleoFire Database, play a critical role achieving transparent and open paleoscientific research by supporting activities including data retrieval and augmentation, stewardship and storage, and laying the foundation for open and well-documented open scientific workflows.

Neotoma’s implementation of FAIR principles extends equally across all aspects of research, data stewardship, citation, and educational outreach. The implementation of Digital Object Identifiers and linked-data landing pages have made data findable and accessible across a number of platforms, including Google’s Dataset Search. Reproducible and accessible online tutorials have improved the delivery and open sharing of educational materials. Investment in open-science workflows as part of the R package development has promoted the use of reproducible workflows in the Quaternary Sciences. As a case study, we will showcase the way each of these elements relate to researchers working with vertebrate fauna. Future steps include efforts to advance the ethical sharing of open data, as elucidated by the CARES principles (Carroll et al., 2020) and enhanced support for additional paleoecological data types such as aeDNA and isotopic data to support multi-proxy ecological research advances in the Quaternary Sciences.

What do we know about mammal diet? How individual diet records can be used to unpack cross-scale processes.

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Organismal diet is an integral part of understanding ecology and evolution because it is how an organism obtains energy. Over the last 20 years, many datasets have provided wide coverage of the diets of mammals. Mammals occupy a wide range of niches, and studying them using these datasets has been instrumental in expanding our knowledge of how diet is related to many ecological and evolutionary processes. These databases have also been key for reconstructing the diets of extinct species and studying community structure changes in the past. These databases, however, do have limitations, as diet is difficult to characterize given the variation in methods, spatial scales, and temporal scales that exist in the literature. Most datasets do not provide the user with the information needed to evaluate questions related to interspecific interactions, intraspecific variation, and diet study variation. Additionally, they often do not have the resolution needed to study processes affecting species that consume a wide variety of foods, such as omnivores. Databases that aggregate individual diet records and incorporate study metadata can be a powerful tool for incorporating these themes into studies of ecological and evolutionary processes. Questions that can be answered using aggregated records are: How many diet studies exist for the mammals of interest? Over how big a geographic area does diet data for a species come from? Does diet vary through time or across space? Aggregated diet records can be used to incorporate sensitivity analyses into projects, study processes across geographic/ecological scales, and find where and on which species new studies should be conducted. To further the utilization of detailed diet records, we aggregated existing diet data for North American mammals in a structure that records study metadata and aligns with databases such as GLoBI, CarniDIET, and the Avian Diet Database. We use case studies to show that by utilizing this data structure from the beginning of a study design, our work on mammal biogeography can investigate diet at various scales (e.g. population vs. continental), allowing for a powerful predictive framework to be unpacked and applied to various ecosystems.

Disruption of trait-environment relationships in African megafauna occurred in the middle Pleistocene

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Mammalian megafauna have been critical to the functioning of Earth's biosphere for millions of years. However, since the Plio-Pleistocene, their biodiversity has declined, concurrent with dramatic environmental change and hominin evolution. While these biodiversity declines are well-documented, their impacts on the ecological function of megafaunal communities remain uncertain. Here, we adapt ecometric methods to evaluate whether biodiversity losses since 7.5 Ma were coincident with disruptions in the functional link between communities of herbivorous, eastern African megafauna and their environments (i.e., functional trait-environment relationships). Herbivore taxonomic and functional diversity began to decline during the Pliocene, as open grassland habitats emerged, persisted, and expanded. In the mid-Pleistocene, when grassland expansion intensified and Acheulean hominin tools emerged, phylogenetic diversity declined, and the trait-environment relationships of herbivore communities shifted significantly. Our results divulge the varying implications of different losses in megafaunal biodiversity. Only the losses that occurred since the mid-Pleistocene were coincident with a disturbance to community ecological function. Prior diversity losses, conversely, occurred as the megafaunal species and trait pool narrowed towards those adapted to grassland environments.

A 6300 years perspective of climate and human influences on mountain vegetation dynamics in the French Alps: a case study located in the Aiguilles rouges (Mont Blanc area).

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Climate change and human activities are highly influencing plant composition/diversity and ecosystems; particularly in mountain areas. It is critical to study how the climate and human drivers affect vegetation composition and plant diversity changes to better i) understand the long-term trend of vegetation dynamics, ii) assess the current status of the ecosystem and iii) get insights into potential future trends of environmental change. Paleoecology is a key discipline to study such long-term perspectives of change. In particular, pollen grains derived from lake and bog sediments can be used as biological proxy to get past vegetation estimates and quantitatively assess vegetation changes from regional to local spatial scales by using Landscape Reconstruction Algorithms (LRA). Pollen-based modelling outcomes can then be compared to paleo climate data and past land-use.

In the present study, sedimentary archives have been collected in the high-altitude Lake Noir (2495 m.a.s.l.). Three cores have been combined and an age-depth model has been created based on 14C dates and XRF analyses for the correlation of cores. The pollen analysis has been conducted on 104 samples, to provide a high resolution record of vegetation history. Then, LRA has been applied to the pollen counts to reconstruct the local (2000m radius around Lake Noir) and regional (20km radius around Lake Noir) plant cover changes over the last 6300 years. Floristic diversity, evenness and Rate of Change have been calculated to assess plant compositional changes and plant-related diversity trends through time.

Between 6300 and 5100 cal. yrs BP, the landscape is dominated by trees and shrubs, with mainly *Abies* and *Pinus*. *Picea* occurs for the first time. From 5100 to 1200 cal. yrs BP an increase of *Picea* and decrease of *Abies* is recorded. We also see the first occurrences of human activity indicators like increased open land taxa. From 1200 cal. yrs BP to present, those open land taxa really increase (Asteraceae, *Plantago,* Poaceae*, Rumex)*, while trees and shrubs decrease, reflecting the opening of lower vegetation belts. Over the last millennium, land use impacts on vegetation compositional indices increase, while climate was the major driver of change over the previous millennia.

Session 83: Quaternary glacier-climate dynamics in the mid & high latitudes of the Southern Hemisphere

Deglaciation of the Hurd Peninsula (Livingston Island, Antarctica)

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Spatio-temporal patterns of glacial retreat determine the intensity of geomorphological, hydrological and ecological processes prevailing in ice-free areas of the Antarctic Peninsula region. Here, the chronology of glacial oscillations following the Last Glacial Maximum (LGM) of the last glacial cycle is still very poor and mostly limited to a few sites next to research stations. Hurd Peninsula, located at the SW corner of Livingston Island (South Shetlands) is covered by the Hurd Peninsula Ice Cap (HPIC), which leaves an ice-free of ca. 20 km^2 in its southern sector, as well as numerous nunataks, which protrude above the ice cap. Its highest elevation is Moores Peak (407 m a.s.l.). To understand the patterns of deglaciation on the peninsula, 30 samples for cosmogenic radiation exposition dating (^{36}Cl isotope) have been obtained from polished surfaces and moraine and erratic boulders, from the highest peaks of the nunataks to the coast. On the most recent moraines, the boulders stabilization has been dated by the diameter of the 10 largest thalli of *Rizocarpon Geographicum*. In this communication, we will present a multiple-dating approach combining absolute surface exposure dating and lichenometry to reconstruct the spatio-temporal patterns of glacial thinning and retreat in Hurd Peninsula. Ice thinning of the HPIC already started before the LGM at ~31.6 ka when the highest areas of the plateau became exposed, and accelerated during the LGM at 20-18 ka. Between 16 and 14 ka, the high plateaus were fully deglaciated. The HPIC was relatively stable until the Mid Holocene, when Neoglacial advances in their fronts were recorded at ca. 4.5 and 2 ka. Finally, the most recent moraines in the HPIC glacial fronts correspond to a period of glacial stabilization that occurred during the Little Ice Age at 0.2-0.3 ka. The internal moraines built during this period correlate well with the glacial advances revealed by lichenometry dated to 1850-1900 CE.

Approaches to reconstruct the timing and nature of glaciation(s) at sub-Antarctic Marion Island

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For paleoclimate studies of the Southern Hemisphere, sub-Antarctic Islands act as important sentinels to assess the nature and timing of Quaternary glaciations. As such, the character and extent of past glaciations on sub-Antarctic Marion Island have remained an important research focus over the last two decades. Here we provide an overview of approaches used to reconstruct the island's past glaciations, starting with a (re-)assessment of geological history and geomorphological evolution. For example, recently available high-resolution satellite imagery and digital elevation data have enabled the detailed mapping of the island's topography and glacial geomorphology. Such spatial data have aided in validating the process-origins of glacial depositional features which can be used to delineate palaeo-ice margins and demarcate possible glacial basins for the reconstruction the island's palaeo-ice extent. Importantly, the application of relative- and absolute-age dating techniques (i.e. rock hardness and cosmogenic 36Cl age dating) have provided exposure ages of glacial features to supplement the spatial data. The combination of mapping and geochronology allowed for the reconstruction of a model showing spatial variation of ice-extent at an island scale since the most recent deglaciation in the Quaternary.

New Holocene glacio-climatic simulations of the Cook Ice Cap on sub-Antarctic Kerguelen Islands

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Understanding the mechanisms of global warming and its impact on human societies is one of the major challenges of the 21st century. In this context, glaciers are excellent indicators of climate because their evolution depends directly on atmospheric conditions through for example temperature and precipitation. Like most of the world's glaciers, sub-Antarctic glaciers are currently undergoing a marked retreat. In the Kerguelen Islands (49° S, 69° E), the Cook Ice Cap has undergone a significant and extremely rapid retreat, losing 20% of its surface area in 40 years, associated with some of the most negative mass balance values observed worldwide.
To better assess the current and future evolution of southern glaciers, it is first necessary to study their past evolution, for which the influence of man is considered negligible. The Kerguelen Islands, due to their geographical location and history, are an exemplary case for understanding past climate mechanisms in the Indian Ocean. Indeed, it harbours well-preserved ancient terrestrial moraines that document the past evolution of glaciers and associated regional climate changes over the last 21,000 years and beyond. Unfortunately, these landforms only provide discontinuous information, both in time and in space. In order to trace the evolution of glaciers over the entire archipelago and the last deglaciation, it is necessary to use glacier-climate modelling.
In this communication, we will present new glacio-climatic simulations of the Cook Ice Cap for the Little Ice Age (~1400-1870 CE) constrained by already-dated moraines around the ice cap. Depending on our progress, simulations for the Antarctic Cold Reversal (□14,5–12,9 ka) or for the Early-to-Mid-Holocene (~10 to 3 ka) might also be presented, in order to understand the climatic mechanisms at work in this southern region of the Indian Ocean. Simulations for the end of the century will also be discussed to provide insights into the future evolution of the ice cap. The simulations will be carried out using two different but complementary glacier models, allowing us to assess the uncertainties arising from the glaciological models, while the use of different climate inputs will inform us of the uncertainty associated with the global climate models.

Patagonian Ice Sheet influence on southern South American climate

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The Last Glacial Maximum (LGM, between 26.5 and 19.0 ka before present) is the closest period with stable climate different from present-day conditions. Among the most striking features is a more than 5°C decrease of global temperature, ~50% less carbon dioxide atmospheric concentration than pre-industrial recent times, and a ~120 m decrease of sea level related to continental ice sheet growth. In the mid-latitudes of the Southern Hemisphere the Patagonian Ice Sheet (PIS) grew over the southern Andes. The PIS extended predominantly in a north-south orientation along ~2000 km, from 38 to 54°S, reaching a mean thickness of 1100 meters. Based on glacial records such as moraines, it is possible to infer the presence of extended glacial lobes to the east of the Andes. However, on the western side of the Andes there is little or no evidence of glacial lobes. Is this difference related to LGM climate? Some authors have hypothesized that the PIS boosted the rain shadow effect generated by the interaction of the Southern Westerly Winds (SWW), the Southern Hemisphere low-level, sub-polar jet, and Andean topography. Today, this interaction generates a variation of the precipitation rate from more than 5 m/a to the west to less than 300 mm/a to the east of the Andes. To evaluate this hypothesis, we performed a sensitivity analysis of the PIS influence on southern South American climate. For this we are running a coupled land-atmosphere model simulation using the Community Earth System Model 2 (CESM 2) with LGM boundary conditions and PIS elevation variations. Results will be presented and discussed in the session. Analyzing variations on temperature, precipitation, storm track frequency, and winds we expect to assess if PIS could have influenced glacier growth during the LGM.

A refined deglacial chronology and ice reconstruction for the Río Pico and Río Cisnes palaeo-outlet glaciers (44° — 45° S), former Patagonian Ice Sheet

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The onset of deglaciation during the Last Glacial-Interglacial Transition (LGIT) remains unconstrained across large parts of the northeastern sector of the former Patagonian Ice Sheet. Here, we aim to address the timing and structure of ice recession associated with two outlet glaciers which occupied the Río Cisnes and Río Pico (44° — 45°S) valleys during the LGIT, and the implications of this pattern of deglaciation for palaeoclimate. We provide refined phases of outlet glacier and palaeolake evolution based on geomorphological, chronological and sedimentological data. The new reconstruction is underpinned by OSL and 14C ages, and a new 10Be and 36Cl cosmogenic nuclide surface exposure-age chronology sampled from boulders on moraines and subglacial landforms.

The Río Cisnes glacier had receded ~30 km by 20.78 ± 1.8 ka from its local glacial maximum position, damming an ice-contact palaeolake at ~950 m a.s.l. The Río Pico glacier experienced a similar ~40 km frontal retreat back to a raised bedrock pinning point by 19.31 ± 1.7 ka, damming Palaeolake Pico at the ~870 m a.s.l. level. At this time, both ice-contact palaeolakes drained east, towards the Atlantic. As ice continued to retreat west into the Andean Cordillera, a spillway opened northwards towards the Río Pico valley, lowering the Palaeolake Cisnes level to ~860-850 m a.s.l. As ice recession continued, and both palaeolakes duly expanded west, drainage reversals took place, allowing new palaeolake drainage routes towards the Pacific. Palaeolake level lowering was initiated by between 16.34 ± 1.4 ka to 16.26 ± 1.4 ka in the Río Cisnes valley, and 17.47 ± 1.5 ka to 17.18 ± 1.5 ka in the Río Pico valley. In the Río Cisnes valley, the onset of local ice-free conditions was punctuated by a re-advance during the Antarctic Cold Reversal (14.5 – 12.8 ka), potentially as a result of the convergence of multiple local cirque ice sources originating from the north and south of the Río Cisnes. Our data provide new constraints on the timing and nature of the last termination in this region of Patagonia, the structure of ice source unzipping, and the phasing of local ice-free conditions.

Postglacial fluctuations of western outlet glaciers of the Southern Patagonian Icefield (Chile, 50°S)

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Postglacial fluctuations of Southern Patagonian Icefield glaciers are well constrained on the leeward side of the Andes, but they remain mostly unknown on the windward side of the icefield, where most glaciers are marine-terminating. Here, we reconstruct the postglacial fluctuations of the HPS19, Penguin, and Europa glaciers along the hyperhumid western side of the Southern Patagonian Icefield using a multi-proxy sedimentological and geochemical analysis of a 12.2 m long sediment core from Wide Channel (50°S). Results show that the glaciers retreated into Penguin and Europa fjords by 11.2 cal. kyr BP and that they were relatively stable and marine-terminating between 11.2 and 5.8 cal. kyr BP. Thereafter, they fluctuated rapidly, with four marked episodes of glacier shrinkage at 5.8 – 4.8, 3.9 – 2.4, 1.0 – 0.2 cal. kyr BP, and during the 20th century. Although the HPS19, Penguin, and Europa glaciers were calving into Penguin and Europa fjords during most of the Holocene, our data suggest that they retreated to land-based positions between 5.8 and 4.8 cal. kyr BP. The comparison of our sediment record with geological archives from both sides of the Patagonian icefields (46° – 56°S) suggests synchronous glacier variability on multi-centennial timescales during the Neoglacial period, which advocates for a regional climate forcing.

Universidad Glacier (34° S) advances during the LGM and late-glacial times derived from a detailed 10Be moraine chronology: paleoclimate implications

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Reconstructing the mid-latitude glacier variations is a prerequisite for unveiling interhemispheric linkages and atmospheric-ocean forcings that triggered those changes in the Subtropical Andes. Nonetheless, the timing, magnitude, and structure of the glacier fluctuations in the Andes of central Chile during the late-Quaternary remain poorly studied. We provide a ^{10}Be chronology (n=23) of Universidad Glacier (34° S, 70° W; ~2500 m a.s.l.) based on ages of boulders resting on discrete moraine belts defining former ice margins. Our findings include the mapping of three moraine belts labeled from the distal to proximal position, located ~20 km, 15 km, and 10 km away from the present-day glacier front. The moraine UNI I extends from the mid to the lowest section of the valley as a kame terrace interrupted by mountain talwegs. The moraine UNI II is composed of a sequence of multiple distinct ridges. The moraine UNI III is a well-preserved single latero-frontal moraine. The exposure ages of moraine UNI I range from 135.9±7.1 to 51.4±2.7 ka (n=3). The mean exposure age of the moraine UNI II is 18.2±1.0 ka (n=14; 1-sigma error). The moraine UNI III yielded a mean exposure age of 12.2±0.7 ka (n=6). The moraine UNI I implies the largest ice extent during a pre-Last Glacial Maximum (LGM) time. The moraine UNI II was deposited during the LGM, linked to a northward-shifted Southern Westerly Winds (SWW). Together with other regional glaciers, paleosol, and marine records, we favor the LGM was a cold and wet period in central Chile. The moraine UNI III represents a return to glacial conditions during the Last Glacial Termination, exposing a double-step deglacial trend observed along the southern Andes and New Zealand at the end of the last ice age. We posit that the SWW migrated north once again at this final stage of the last glacial-interglacial transition to trigger this glacial advance. A tropical forcing for this glacial advance should be discarded because, given the latitude of central Chile, our study site lies in the domain of the extratropical SWW. We suggest that the SWW dominated the late-Quaternary glaciations in the Andes of central Chile.

10Be chronology of Late Pleistocene to Holocene glacial fluctuations in the Río Limarí basin (30-31º S) in the Andes of central Chile

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Glacier chronologies in the southern mid-latitudes are suitable to track past latitudinal variability of the southern westerly winds (SWW) through the last glacial period and into the Holocene. Nonetheless, most of the available records along the southern Andes have focused on the temperate areas south of 40° S, leaving a gap in the extratropical semiarid Andes at the northern limit of the SWW influence. Here we present a new detailed ^{10}Be chronology of glacier fluctuations in the Río Limarí Basin (30-31° S). We selected four formerly glaciated valleys ranging between 3000 and 5000 m a.s.l.: Toro and Las Arenas (Combarbalá sub-catchment) and El Viento and El Seco (Río Hurtado sub-catchment). Quartz-rich granitic lithologies make up the rocks there. The glacial imprint is conspicuous, typical for a formerly glaciated mountain landscape including u-shaped valleys, cirques, and aretes containing a distinct glacial drift. We mapped multiple moraine belts, up to five in some valleys.

The outermost moraine is preserved as a prominent, elongated boulderly ridge widened at the top. Boulders expose a weathered layer a few centimeters thick and are embedded in the so-called “maicillo” matrix. In some cases, striated boulders are present. The next moraine belt is a prominent hummocky terrain extending along the valley bottom from side to side, better described as a dead-ice moraine. This moraine is punctuated by distinct moraine ridges that represent former active ice marginal deposits, with faceted and striated boulders. In some cases this glacial drift can be tracked to near actual cirques, where Holocene moraines and active rock glaciers are found.

We applied ^{10}Be exposure dating on boulders resting in stable positions on moraine crests of different generations to build a chronology encompassing the last glacial period and its termination. Preliminary ages suggest glacial advances during the pre-last glacial period and the Last Glacial Maximum (c. 26-18 ka). One moraine seems to have been deposited possible during MIS 3 or MIS 4. Finally, we discuss ages and their paleoclimate implications in the light of previous work in the region (e.g., Zech et al., 2007, 2017; Aguilar et al., 2022).

Session 84: Extending the limits of ice core science beyond new analytical, conceptual and inter-disciplinary frontiers

The quandary of detecting the signature of climate change in Antarctica

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The current global warming driven by human activities has been accentuated in Polar Regions due to the polar amplification, resulting in large releases of ice that have impacts on circulation and sea level at the global scale. In the Arctic, the temperature has increased at three times the global rate, and lead to significant melt of the Greenland ice sheet and sea ice decline. Yet, for Antarctica, the impact of warming is still poorly constrained given the lack of instrumental data and the large decadal climate variability. Using a compilation of 78 ice core records, we provide a high-resolution reconstruction of past temperatures over the last 1000 years for seven regions of Antarctica and direct evidence of Antarctic polar amplification at regional and continental scales. We also show that both the natural and forced variability are not captured by pseudo-proxy experiments using the CMIP5 and 6 ensembles. This that the feedback loops causing the polar amplification are not properly taken into account, leading to an underestimation of the magnitude of anthropogenic warming and its consequences in Antarctica.

New ice core proxy for reconstructing past wind variability in the Atlantic sector of the Southern Hemisphere Westerly Wind belt

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The Southern Hemisphere Westerly Winds play a critical role in the global climate system by modulating the upwelling and the transfer of heat and carbon between the atmosphere and the ocean. Since observations started, the core of the westerly wind belt has increased in strength and has contracted towards Antarctica. It has been proposed that these deviations are among the main drivers of the observed widespread warming in West Antarctica. However, the lack of long-term wind records in the Southern Hemisphere mid-latitudes hinders our ability to assess the wider context of the recently observed changes.

Here, we present records of marine diatoms preserved in a series of ice cores from Ellsworth Land, West Antarctic. The diatom abundances and species assemblages from these ice cores represent the regional variability in wind strength and atmospheric circulation patterns. We use this novel proxy to produce an annual reconstruction of winds in the Atlantic sector of the Southern Hemisphere Westerly Wind belt over the last 300 years. This wind reconstruction allows us to track changes in the strength and position of the westerly winds during the Little Ice Age and explore the link between the recent increase in wind strength, greenhouse gases and ozone depletion in the atmosphere.

Improving ice core nitrate interpretation through a decade of monitoring at Dome C

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Nitrate (NO_3^-) deposited from the atmosphere is one of the most common ions found in Antarctic snow and glacial ice. Recently, we have shown that the $d^{15}N$ isotopic ratio of nitrate can be used as a quantitative proxy for snow accumulation in Antarctica due to isotopic fractionation during post-depositional photolytic mass loss. Here, we expand upon this premise to better constrain the range and drivers of small scale NO_3^- variability across time and space. We achieve this through the culmination of over a decade of monitoring NO_3^- at Dome C comprising 385 weekly atmospheric samples, over 1700 3–5 day snow surface samples, and 132 monthly snow pits. This continuous monitoring program was supplemented by a trench study at Dome C in December 2019 where 1 m vertical NO_3^- profiles were sampled repeatedly along a 50 m transect. We find that atmospheric and surface snow NO_3^- follow clear seasonal cycles with generally consistent mean values from 2009 to 2021. The interannual $d^{15}N$ variability due to variable weather, insolation, and NO_3^- transport for a given week of the year, however, can be as large as 20 ‰ and 60 ‰ for atmospheric and surface snow NO_3^-, respectively. Snow pit monitoring reveals that $d^{15}N$ from equivalent depths may vary by over 100 ‰ between monthly samplings a few meters apart. We find similar observations in our trench study, with same depth $d^{15}N$ values varying up to 150 ‰ in as little as 4 horizontal meters. This small scale spatial variability largely results from local surface features like drifts that affect photolytic activity on a meter to meter scale by altering local accumulation and snow grain character. This observed temporal and spatial variability reveals the need to replicate and aggregate multiple samples spread over an area >100 m^2 if one aims to collect a NO_3^- sample that is broadly representative of a site. Additionally, we expect NO_3^- recovered from ice cores to exhibit artifacts of this small scale variability due to its single point nature, and we argue that high resolution NO_3^- data likely needs some level of aggregation to reduce these artifacts.

Age-depth relationship for Beyond EPICA using radar measurements and ice flow modelling

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This work is part of the network of DEEPICE PhD projects associated with the Beyond EPICA drilling project which aims to recover a continuous 1.5 million year old ice core from Little Dome C in Antarctica.
Over the past 5 years, 3 sets of radar measurements were taken (UT, BAS, AWI/CPH/UA) around the area of interest for the Beyond EPICA project. With the preparations of the Beyond EPICA Little Dome C drill site (BELDC) completed in the 21/22 season, we now use a combination of radar observations and numerical models to understand the age-depth distribution and dynamic properties of the ice in the area surrounding the drill site.
Several internal horizons have been traced and dated by linking them to the 800 ka old European Dome C ice core. We combine a 1D numerical model which uses inverse methods, constrained by the traced radar horizons and the AICC2012 EDC core accumulation profile.
Modelled results include the age of ice and thickness of a layer of stagnant ice along the radar lines for each of the 3 radar datasets. At BELDC, the average modelled age 60m above the stagnant was around 1.5 million years. We compare the thickness of modelled stagnant ice with that of the basal layer observed in the most recent measurements, and propose that they are the same.
These modelled results are directly relevant for the Beyond EPICA project and for the Australian team also planning to drill at LDC for the Million Year Old Ice project. With radar measurements from other areas in Antarctica the model could be applied to other planned drill projects such as those of Japan, China and the US. Currently, our 1D model is appropriate around ice sheet domes. We plan to develop a 2.5D model which takes into account horizontal ice flow, so it could model regions of Antarctica with more varied topography.

How to extract climate signals in deep ice through model-assisted exploitation of high-resolution impurity analysis

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Climate signals from ice cores are conventionally extracted through the use of continuous flow analysis (CFA) at centimeter resolution. The European project Beyond EPICA Oldest Ice (BE-OI) aims to retrieve ice from the bottom of the Antarctic ice sheet. It is expected that this ice will contain more than 14,000 years of climate history per meter depth, calling for analysis to be conducted at a depth resolution beyond the limits of CFA. To extract the climate signal while best conserving ice samples we must use micro destructive techniques with high resolution, such as laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). Images obtained using LA-ICP-MS have shown that the impurity distribution, and therefore the impurity-derived climate signal, is influenced by the various interactions of impurities with the ice matrix. In deep ice with crystal sizes on the order of centimeters or greater the question remains: on which time scale can the climate signal be expected to be preserved?

To both aid the extraction of the climate signal using LA-ICP-MS and secure a link between CFA and LA-ICP-MS output a computational model was developed. The model is based on simple assumptions about ice crystal growth and impurity distribution. Using this model, an artificial ice volume analogous to the samples conventionally melted during CFA is simulated. Interrogation of this system brings insight into the spatial distortion of the climate signal, first and foremost due to the relocation of impurities by grain growth. It also helps us to better understand the similarities and differences between CFA and LA-ICP-MS observed in the model and in laboratory measurements. Through comparison of the model output with experimental results the link between the climate signal, CFA measurements, and LA-ICP-MS measurements will be discussed and the optimal LA-ICP-MS depth resolution for climate signal extraction constrained.

Elemental record of impurities in the Talos Dome ice core: a study on solubility of elements at different depths

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We present a record on the elemental composition of impurities present in the Talos dome ice core at different depths. Insoluble fraction of dust was investigated with low background instrumental neutron analysis (INAA) while inductively coupled plasma mass spectrometry (ICP-SFMS) was applied to two different set of samples to observe both the total composition and the soluble fraction of impurities in the ice. In order to do so, the first set of samples was only leached while the second one was also filtered to remove dust particles > 0.2µm. We determined 45 elements through ICP-SFMS and 39 through INAA, with a good overlapping of the elements between the two techniques. Besides the determination of major elements (Na, Mg, Al, Si, K, Ca, Ti, Mn, Fe), the high sensibility of both techniques also permitted the determination of trace elements. Among these, rare earth elements (REE) are of particular importance as they have been widely used as a geochemical tracer of aeolian dust sources. The wide range of elements considered in this study gives us the possibility to study links between different elements at different depths. Our principal aim was to study the fractionation of elements between soluble and insoluble phase and how this may change at different climatic stages. Shifts in the fractionation of some elements between soluble and insoluble phase can be an indicator of a modification in the dust sources, but may also point to post depositional processes taking place inside deep ice. Overall, the majority of elements showed a minimum in solubility during the last glacial maximum as a result of higher fluxes of mineral dust which were transported to the Antarctic Continent from remote sources. Iron was the only element to display a clear decrease of solubility at increasing depth linked to chemical weathering processes, highlighting the high sensitivity of this element with respect to post-depositional processes.

Origin of last glacial ice core dust in central Greenland

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High-resolution ice core oxygen isotope records reveal that the generally cold last glacial climate was interrupted by numerous rapid shifts to warmer interstadial conditions, called Dansgaard–Oeschger (D–O) events. This D–O type climate variability is coupled with variations in dust concentration and particle size, with rapid decreases in Ca^{2+} ions at the onset of interstadials and slower increases following their end. These abrupt variations in dust characteristics have variously been accounted for by changes in transit and atmospheric residence time, transport distance, extent and intensity of the polar atmospheric cell, dust source strength, aridity, and storminess, nevertheless the precise causal mechanisms of these changes remain elusive. The NGRIP ice core record demonstrates synchrony in variations of Ca^{2+} concentration and $\delta^{18}O_{ice}$ indicating that the climate of continental dust sources and Greenland must have been coupled. However, the mechanisms of this coupled response over wide areas of the Northern Hemisphere (NH) remain poorly constrained. Resolving the source(s) of Greenland ice core dust is a key step in resolving the uncertainty over this coupling, as it allows the environmental controls on dust emission to be constrained, as well as providing insight into major dust transport pathways and atmospheric circulation patterns during abrupt climate events of the Last Glacial Period. A multi-technique analysis of Greenland dust provenance is presented, using novel and established, source diagnostic isotopic tracers as well as results from a regional climate model including dust cycle simulations. We show that the existing dominant model for the provenance of Greenland dust as sourced from combined East Asian dust and Pacific volcanics is not supported. Instead, clay mineralogical, Hf–Sr–Nd and D/H isotopic analyses from last glacial Greenland dust and an extensive range of NH potential dust sources suggest three most likely scenarios (in order of probability): direct dust sourcing from the Taklimakan Desert in western China, direct sourcing from European glacial sources, or a mix of dust originating from Europe and North Africa. Furthermore, our regional climate modelling demonstrates, for the first time, the plausibility of European or mixed European/North African sources.

Session 85: Loess and dust deposits: beyond local studies

Paleodust during the last climate cycle: a data-model comparison

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The Last Climate Cycle (LCC, 130-15kyr) has shown cold, dusty (GS) and warmer, non-dusty (GI) intervals, when the atmosphere was 2-20 times more loaded with dust than today. The alternations between GS and GI occurred on millennial time scales, involving climate forcings other than orbital. The transition between GS and GI lasted on average 50 yrs, resulting from a complete climate reorganization that is not presently understood. A data-model project, has acquired and investigated European loess sequences to get high-resolution and well-dated paleodust records of the LCC showing Europe experienced millennial paleodust variations through paleosol-loess unit alternations. Similarly, Chinese loess sequence recorded millennial paleodust variations expressed by grain-size oscillations. These are apparently similar to those initially observed in Europe, although the timing of dust sedimentation does not seem to be identical. Earth System Models contribute i) to characterize the source regions of the paleodust and ii) to reproduce past variations in dust deposition for key paleoclimate scenarios. A key component of the project analyses loess samples dated from the last glacial maximum to detect the origin of the deposited material. A first study on the bulk sediment demonstrates that the paleodust deposited over Europe along a long longitudinal transect (about 2000 km) indicates a short distance transport implying local to regional source. Targeting the <2 mm and 2-20 mm grain size fractions and comparing with the previous results from the bulk samples, preliminary results for Western Europe sites, indicate a local to regional origin for the coarse (2-20 mm and bulk) material and a more distant source for the finer fraction (<2 mm), involving longer transport in relation to general atmospheric circulation, for the finer particles. This is a critical new research question because it implies potentially important order of magnitude regional variations in dust radiative forcing that have never been accounted for in simulations of abrupt events.

Evidencing and dating the impact of millennial time-scale climatic events (DO cycles) in Western European Last glacial loess records

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The *European Loess Belt* is the most extensive continental archive of the last glacial period (Weichselian / MIS 5d-2) in Europe. Located downwind of Westerlies, south of the British-Irish and Fennoscandian ice sheets and north of the englaciated Alps, this area was ideally located to record the impact of global millennial-timescale climate variations (Dansgaard-Oeschger (DO) cycles, Heinrich (H) events) triggered by the North Atlantic Ocean circulation during the last glacial period. Furthermore, its northwestern part also recorded numerous evidences of permafrost and periglacial processes such as large ice wedge networks or thermokarst erosion processes, which are connected with ice-rich permafrost environmental phases marked by the development of tundra gley horizons. Our high-resolution stratigraphic approach shows that their distribution can be followed over long distances at least to Belgium and western Germany. Moreover, the demonstration of the connexion between millennial-timescale warming events (interstadials) and tundra gley formation is now possible owing to a new ^{14}C dating approach developed by our team on earthworm calcite granules extracted from 15-30cm thick tundra gley horizons. The accurate dating of the tundra gley layers demonstrates the occurrence of several generations of ice-wedge cast networks that appear to have developed and degraded only during short phases ($\leq$ 1 ka) as revealed by detailed correlations with the North GRIP climate record. These features typify specific palaeoclimatic conditions that are however still to be characterised in the frame of a modelling approach involving inlandsis and sea-ice extent, atmospheric circulation and temperature reconstructions. Otherwise, high-resolution sedimentological and malacological investigations combined with earthworm granules ^{14}C dating demonstrated that the response of loess environments to Dansgaard-Oeschger cycles is recorded by the formation of a rich and complex stratigraphic succession of loess-palaeosol cycles corresponding to as many stadial-interstadial cycles between about 50 and 20 ka. These works therefore make it possible to describe, over the long distance, the response of glacial continental environments to past millennial-timescale climate variations and provide a strong database for the discussion of human-environment relationships during the Last Glacial.

The loess-palaeosol section of Baix (Rhône Rift Valley, SE-France): a unique Late-Pleistocene record of the transition zone between the presently temperate and the Mediterranean region of Europe

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Loess-palaeosol sections (LPS) provide valuable archives of Quaternary palaeoenvironmental changes over time, and spatial palaeoenvironmental gradients during the same period. Here we present the LPS Baix, located at the western edge of the Rhône Rift Valley in southeastern France, at 44°42'36" N and 4°43'21" E. Already discovered in 1934, this 14 m thick LPS has never been studied employing modern analytical methods. It caught our attention because it is located in the transition zone between the presently temperate and the Mediterranean region of Europe. To our knowledge, no LPS has been analysed yet in such a transitional climatic position. It likely provides a crucial link between the rigorously analyzed LPS in the presently temperate regions further north (e.g., in northern France, the Alsace region and Germany) and the LPS in the Mediterranean region (e.g., in southern France, Catalonia, Italy and Croatia). Therefore, we aimed at deciphering the paleoenvironmental record of the LPS Baix in this particular transitional climatic position. We analysed the LPS Baix by means of sedimentological and palaeopedological methods combined with OSL and ^{14}C dating of mollusc shells. Reddish Btg horizons of a Stagnic Luvisol at the base of the LPS represent the remains of an Eemian to Early Würmian (MIS 5) pedocomplex formed under warm and - at least temporarily - relatively moist conditions. Two brown Bw horizons of truncated Cambisols have been preserved in the overlying early to middle Pleniglacial (MIS 5a/4 and MIS 3) deposits. The upper Bw horizon is associated with large carbonate nodules, indicating that considerable amounts of calcium carbonate were leached from the former middle Pleniglacial Cambisol and accumulated in the underlying loess unit. This truncated middle Pleniglacial Cambisol is very similar to the middle Pleniglacial palaeosol remains in the LPS Collias that we investigated 87 km further south, near Nîmes, in the present Mediterranean climate. No palaeosols were observed in the late Pleniglacial deposits of the LPS Baix.

Quaternary sediment routing: provenance and spatial variation of loess deposits in the East European Plain and Caspian Sea region

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The East European Plain (EEP) is a vast and geomorphologically variable area with numerous interacting climate systems. Widely glaciated by the Fennoscandian Ice Sheet during the Quaternary, it comprises several complex, interacting sedimentary systems, controlled by glacial, periglacial, fluvial, aeolian and marine processes.
Three major river systems drain the current EEP into the Black Sea and the Caspian Sea in the south, the Volga, the Don and the Dnieper, and both Caspian and Black Sea water levels and long-range sediment transport are heavily influenced by their drainage. The EEP is blanketed by extensive loessic and sandy aeolian deposits, as well as marine, fluvial and alluvial sediments and sediment routing may show complex patterns and controls. As a result, the provenance and transport of loess in this complex and highly dynamic environment remains poorly known.

The Quaternary EEP has multiple potential loess sources. In addition to the Fennoscandian Ice Sheet, surrounding mountain ranges as well as more distal orogens to the east and their palaeo-drainage systems may provide extensive sediments and represent loess source regions. Furthermore, desert areas lying to the east of the South Caspian Sea combine the potential of being a sediment sink for material from mountains, as well as a secondary source for the Caspian Sea region and the large loess area in northern Iran.
Here, a first large-scale reconstruction of Quaternary sediment sources, transport pathways and sinks for the EEP and southern Caspian Sea region is established based on large-n U-Pb dating of detrital zircons. Our results reveal that sedimentary sinks in the region are sourced from a range of places and that sediment supply is mainly linked to continental and mountain glaciation. The distribution of the material over a wide area and long timescales is mostly undertaken via rivers prior to near source aeolian and marine reworking and transportation. A strong spatial variability of loess sources, even over small areas, indicates input from multiple local dust sources.

Lower Danube paleoclimate records and rapid climate variability during the last glacial cycle

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Here we present results of detailed high-resolution sedimentological, geochemical, and chronological investigations of several long loess profiles from the Lower Danube area. Our loess data show distinct variability that correlate well with shifts in paleoclimate records from Greenland ice cores and Northern Hemisphere speleothem records over the last glacial cycle. These features in loess data, most prominent in the magnetic susceptibility and grain-size data, are complemented by information from geochemical proxies and provide important insights into the nature of the depositional environment.

To assess the paleoclimatic significance of our proxy data results are further compared with regionally representative lake, loess, speleothem and marine stacks from Black Sea, Mediterranean and the Northern Hemisphere. The comparison reveals consistent millennial-scale variability (e.g., fluctuations that resemble stadial-interstadial events) archived within the proxy data and identification of common features that allow for the synchronization of records (aided also by tephrochronology) over the last glacial cycle. Such chronological synchronization of the loess records with other paleoclimate archives with high confidence on millennial time-scales further allowed revealing some less pronounced but intriguing differences. The results illustrate the value of a multiproxy multi-site approach in understanding sediment dynamics and variations in processes influencing/controlling loess-paleosol formation during rapid climate changes such as stadials and interstadials. Hence, loess archives so far widely underestimated are in many aspects directly comparable to well established paleoclimate archives and significantly improve the spatial resolution of Eurasian-wide paleoclimatic data.

Connecting loess archives in the Western and Eastern Mediterranean

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Within the broad field of loess research, studies on Mediterranean loess sections are heavily under-represented considering their great value for reconstructing palaeoenvironmental conditions during the Quaternary period. Taking into account the displacement of atmospheric circulation patterns, especially during stadial phases, the Mediterranean realm has often fallen into the transition zone between polar and subtropical air masses. Hence, these areas are particularly suitable for investigating the influence of different atmospheric systems, e. g. the westerlies, on past landscapes and environments.
Here we present the main results of several research projects dealing with loess dynamics in the Western Mediterranean (central Spain) as well as the outermost Eastern Mediterranean (northeastern Armenia, Southern Caucasus). Apart from the most important stratigraphic and geochronologic patterns, we demonstrate selected proxy information that enable a detailed reconstruction of palaeoenvironments linked to loess formation as well as pedogenesis. The integration of regional terrestrial archive information, e. g. on glacier advances or vegetation dynamics, further help to improve the picture of the environmental framework for the buildup of Mediterranean loess sequences.
Finally, the attempt is made to connect both loess archives and also include marine archive information for providing a very general idea of last glacial climate-related environmental changes over the Mediterranean area.

Age and palaeoenvironmental interpretation of the ice-wedge pseudomorphs recorded in the Last Glacial loess-palaeosol sequences in Poland and western part of Ukraine

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The North European loess belt was formed in cold climatic conditions in the periglacial zone of the Pleistocene continental glaciations. Unlike many others loess areas, periglacial loess was deposited during short but intense sedimentation phases strongly coupled with the dynamics of the glacial system.

Three types of periglacial structures are useful to reconstruct the former periglacial environment: cryogenic wedges with primary mineral infilling, cryoturbation and gelifluction structures, and ice-wedge pseudomorphs. These structures frequently form marker horizons, which suggests their relation with global and/or regional climate changes.

Among many periglacial phenomena, only some indicate unequivocally the presence of fossil permafrost. The most important are ice-wedge pseudomorphs, which are reliable evidence of former permafrost. Each generation of ice-wedge pseudomorphs proves that the temperature thresholds have been exceeded twice. They document significant cooling and subsequent warming of the climate. However, there are still problems with determining the genesis of many pseudomorphs, which complicates the possibility of their reliable palaeoenvironmental interpretations.

Taking into account a spatial distribution of Last Glacial ice-wedge pseudomorphs it can be stated that in the central and eastern part of research area the permafrost had developed at least twice. The older (MIS 4) generation indicate their development in conditions between continuous and discontinuous permafrost. The common occurrence and large size of the younger generation of ice-wedge pseudomorphs (MIS 2) indicate continuous permafrost in this part of the research area. However, there are some evidences of partial decay of permafrost during the early MIS 2 what can be interpreted as a presence of rapid short-term warming around 23 ka years ago. In the western part of Poland the evidence of MIS 4 permafrost were found only in northern part. During the MIS 2 loess area in western Poland were occupied within both continuous and discontinuous permafrost.

Field observations in the extensive exposures of Podolia and Volhynia indicate the presence of more complex ice-wedge pseudomorphs. In addition to epigenetic forms, there are syngenetic forms that more accurately document the subsequent stages of development and disappearance of permafrost.

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Session 87: Prehistoric hunter-gatherers' adaptation during the Last Glacial in Europe

Neanderthals' adaptations during the Weichselian in Central Europe

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During the Weichselian (MIS 5d - MIS 3), the climatic deterioration and the rapid decrease of the temperatures caused significant difficulties for Neanderthal groups that had to adapt to new environmental changes. Central European Neanderthals reacted to these cooler ecological conditions by designing a new toolkit composed of asymmetric bifacial knives, bifacial tools, foliate artifacts, and coin-like scrapers (groszaks). This new cultural facies of the Late Middle Palaeolithic is named Micoquian (or Central-Eastern European Micoquian – CEEM) spreading from Eastern France to Poland, Northern Caucasus, and Altai. This paper presents new technological data from several Micoquian sites in Germany and southern Poland. Our results indicate different technological trajectories in the emergence and development of these new stone tools related to the ecological settings, site function, and animal prey. Further comparisons with other Micoquian sites in Central-Eastern Europe and its fringes will reveal the Neanderthals' flexibility in land use during environmental changes.

Neanderthals in changing evironments from the Eemian to the early Pleniglacial – New evidence at the site of Lichtenberg, Germany

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The question of how Neanderthals adapted to changing climatic and environmental conditions, and in particular to severely cold climates in northern regions of Central Europe, is far from being resolved. Establishing direct links between occupations and associated environments may be facilitated by the investigation of suitable multi-layered sites that can provide the respective behavioral, chronological and palaeoecological evidence. Here we present the results of our integrative research carried out at the Middle Palaeolithic open-air site of Lichtenberg, Northern Germany. Our set of methods comprises archaeological approaches, luminescence dating, sedimentology, micromorphology, as well as pollen and phytolith analyses. Through an extensive sediment coring campaign, we deliberately included the immidiate surroundings into our investigations, thus gaining valuable contextual information about past landscape-forming processes. These surveys led, among other things, to the discovery of two previously unknown Neanderthal occupations in Lichtenberg.

Our results show that Neanderthals were present in temperate, forested intervals during the Mid-Eemian Interglacial (MIS 5e) and the latest Brörup Interstadial (MIS 5c/GI 22, occupation Lichtenberg II). We further propose a revision of the chronology for the previously known occupation Lichtenberg I: Instead of the early MIS 3 (mean TL age of 57 ± 6 ka), according to our data, the occupation rather took place in the early MIS 4/GS 19 (mean pIRIR age of 71.3 ± 7.3 ka), with dominant cold steppe/tundra vegetation and periglacial characteristics of the embedding sediments.

The artefact assemblages of these temperate to cold environment occupations differ with respect to size, blank production, typology and tool use. We argue that this distinctness can partially be explained by different site functions, tasks and occupation durations, but also by the availability of large and high-quality flint raw material, provided by the respective magnitudes of sediment redeposition from nearby Saalian glacial sediments.

Middle-to-Late Pleistocene magnetostratigraphic records from Loess-Paleosol Zwierzyniec sequence (Krakow, Poland): a correlation between geomagnetic excursions and main archeological levels

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We present new paleomagnetic data and rock magnetic results from the sedimentary sequence of the site Kraków-Zwierzyniec 1, located in Krakow, southern Poland. Kraków-Zwierzyniec 1 site represents one of the most important Paleolithic sites of Central Europe, where several archeological layers, respectively associated with Levallois-Mousterian, Micoquian, Szeletian, Zwierzyniecian, and Aurignacian, were discovered. Archaeological levels are embedded into a loess-palaeosol sequence, alternating thick silty layers to shallow soil horizons marked by accumulation of organics, weak weathering, and evidence of frost-related pedoturbation. Continuous wind sediments – as the Zwierzyniec sequence is – are usually considered one of the most suitable deposits for Quaternary paleomagnetic studies, thus we collected a total of 228 superposed paleomagnetic samples to define a high-resolution stratigraphic chronology of the Palaeolithic site. Magnetic directions, dominated by normal polarities, were isolated through thermal cleaning, and were compared with a dated palaeosecular variation (PSV) reference curve from the literature. In addition, samples have also been investigated for relative palaeointensity (RPI) using rock-magnetic parameters (ARM/NRM) at various AF demagnetization steps. The derived RPI curve is then compared to dated RPI records from the literature to augment the chronology of the investigated section. We also investigated the main magnetic assemblages of the loess-palaeosol sequence, as well as the magnetic properties, defining that the magnetization has been mainly acquired by ferrimagnetic minerals (i.e., magnetite grains). Throughout the whole section, several Optically Stimulated Luminescence (OSL) samples were also collected. The ultimate scope of this study is to generate an age model of deposition for the investigated sequence by integrating PSV, RPI, and OSL data, thus offering a fresh geochronological context to archaeological findings.

Comparison of the Neanderthal and Anatomically Modern Human niches in MIS 4 and MIS 2

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Applying ecological niche modelling to the extinct hominin species is a relatively new approach for increasing the understanding of key pressures involved in evolutionary processes. How have different species of *Homo* dealt with climate changes? Were the extinctions brought about by climate change or only speeded up by it?

As the Neanderthals - *Homo neanderthalensis*, one of the few European species in the hominin ancestry, are the closest to us in a temporal sense and present many similarities to our own species, such as the capacity for symbolic expression (Moncel et al. 2012), and speech (Johansson 2013), they are a valid comparison to Anatomically Modern Humans (AMH).

Their landscapes and climate were unfamiliar to ours as we know them now. The open, steppe-like landscapes that dominated Europe in the prime of the Neanderthals had good exposure to sunlight and rich vegetation that sustained considerable populations of mammoth, bison, deer, horse and reindeer – species fundamental to their diet. Neanderthal and AMH landscapes through various marine isotope stages did differ from each other (Helmens, 2014). However, they were nothing like the barren steppes of present-day Eurasia or any landscapes in today's world.

We have modelled the niches of Neanderthals from MIS 4 (57-71 KYA) and anatomically modern humans (AMH) from MIS 2 (KYA), as both MIS represent cold periods, and then compared these models to each other. These models, created using Maxent (Phillips, 2005), used presence data of sites with a high certainty attribution to the species based on the human remains found at the sites and statistics-based climate reconstruction data (Krapp et al. 2021). The resulting models show the environmental niche of Neanderthals and AMH, which helps us understand them as people, their climatic requirements, and ecological preferences from the glacial periods, those, coupled with geological data, the results can open new prospects for finding additional sites, as well as help us understand possible causes of Neanderthal disappearance.

Spatiotemporal pattern of Neanderthal extirpation and plausible ecological drivers

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Variation in the distribution of ecosystem resources driven by climate shifts have influenced the mobility and dispersal of hunter-gatherer Neanderthals and *Homo sapiens*. Neanderthals disappeared while early *H. sapiens* successfully migrated through Eurasia during marine isotope stage 3 (~ 57,000 to 29,000 years BP). This interstadial phase was characterised by intense, millennial-scale climate variability, with large shifts in winter temperatures and precipitation. Recent attempts to estimate the terminal dates and drivers of Neanderthal extinction support disappearance around 42,000 years BP, with this timing and the relative influence of different extinction drivers varying regionally (e.g., changes in resources availability via changes in ecosystem productivity and competition with *H. sapiens*). However, most of the conclusions for potential drivers rely on mechanistic approaches as archaeological evidence is often sparse and incomplete, thus making the reconstruction of regional patterns of Neanderthal extinction challenging when independent datasets are viewed in isolation. Here, we applied a spatiotemporal statistical model to high-quality Neanderthal fossil records (i.e., suitable dates on securely identified fossils) to generate a spatial and taphonomically bias-corrected extinction map of the chronology of Neanderthal extirpation. We then quantified the relative role of climate change in explaining this pattern of Neanderthal extirpation, by statistically comparing it to regional variation in hindcasted climate conditions derived from climate hindcasts. We show that Neanderthal extinction was a long-term process that occurred from middle and late marine isotope stage 3 (~ 45,000–29,000 years BP), and we identify areas where Neanderthals possibly coexisted with early *H. sapiens*. We discuss how these new timelines provide insights on the extent to which variation in food resources has shaped the Neanderthal population in Western Europe prior to full extinction, potentially promoting the expansion of early *H. sapiens*.

Testing the synchrony between cultural and paleoenvironmental changes in southern France during the Middle-to-Upper Palaeolithic transition

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Determining the impact of climatic variations on past human cultural changes is a difficult task due to the chronological uncertainties inherent to the dating methods applied to archaeological and paleoclimatic archives, and by the different temporal resolution of both archives.

Here, we present two high-resolution pollen-based palaeoenvironmental sequences from the Bay of Biscay (45°21'N, 5°13'W) and the Gulf of Lion (40°29'N, 4°01'E) plotted against up-to-date chronologies. These sequences unambiguously identify millennial-scale vegetation and climatic changes in southern France in response to Greenland warming and cooling events, *i.e.* Dansgaard-Oeschger (D-O) cycles, and to the North Atlantic major iceberg discharges called Heinrich events (HEs). The chronologies are well constrained by numerical dating (new IRSL ages for the Bay of Biscay deep-sea core) and new age-depth models, based on Bayesian statistics and stratigraphic constrains using ChronoModel software and R-package ArchaeoPhases.

The construction and updating of archaeological databases for the Middle-to-Upper Palaeolithic transition in southwestern and southeastern France has allowed the development of age models based on ChronoModel. These age models provide more reliable chronological windows for the observed cultural changes in Neanderthals and Anatomically Modern Humans (AMH) in Western Europe.

Despite the improved paleoclimatic and archeological chronologies, the identification of a potential synchrony between climate and cultural changes still remains difficult due to new uncertainties. Nevertheless, this study suggests that the progressive opening of landscape since the D-O 12 (~47 ka) favoured the arrival of AMH in Western Europe, leading to competition with Neanderthals for the same ecological niches, and thus to the disappearance of the latter at ~40 ka.

The fundamental role of radiocarbon to forecast possible scenarios of human/environment dynamics during climatic fluctuations.

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Chronology is the basal aspect of Paleolithic Archaeology, and precise absolute radiocarbon dating is crucial for understanding the timing of cultural events that occurred in the past. In fact, understanding the timing of dispersals of *Homo sapiens* in Europe, the interaction with Neanderthals, the extent of their temporal overlapping in the different regions, and the interplays between hominins and climatic fluctuations is a research topic that requires high accuracy and precision in radiocarbon dating. Today the radiocarbon dating method is even more intertwined with the field of archaeology and is part of those applied sciences that never stop being improved, to be revolutionized in some way. In fact, for the past 14,000 years, the radiocarbon calibration curve has been highly precise and of high resolution (annual to a decade) due to tree-ring chronologies, but it is still rather coarse in Middle to Upper Paleolithic, where the carbon archives are connected only indirectly to the atmosphere (speleothems, coral reefs, marine and lake sediments). However, the resolution of radiocarbon in the Glacial will be improved by new findings of Glacial trees in New Zealand (Kauri) and in the Mediterranean (Italy, Portugal), linked to the ice-core timescale via another cosmogenic isotope, Beryllium-10. Using these tree-ring-based data, we can begin to calibrate more accurately the 14C ages associated with breakthrough discoveries of human evolution. This study presents new data of high-resolution radiocarbon chronologies of several Middle and Upper Paleolithic sites showing how 14C dates with thigh error ranges could improve the understanding of archaeological human occupations and the association with past climatic fluctuations.

Initial and Early Upper Palaeolithic blade and bladelet technologies in Eastern Balkans (MIS 3): Chronological and climatic indications, taphonomical and techno-economical evidence from Bacho Kiro, Temnata and Kozarnika caves

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The Initial Upper Palaeolithic blade technologies at Bacho Kiro Cave are now securely associated to Homo sapiens dispersal in Eurasia between 45 and 43 ka BP. The chrono-stratigraphic record from the regional benchmark Palaeolithic sites Temnata and Kozarnika caves can be compared and reconsidered. This study assesses contextual information, chronological markers (radiometric dates and Campanian Ignimbrite (CI) Y-5 tephra), lithic technologies, fauna, climatic data and worked bone assemblages to discuss the establishment and duration of the IUP in southeast Europe and the connection with the subsequent Early Upper Palaeolithic bladelet industry from Kozarnika Cave.

This contribution aims to synthesize the pertinent data and expose the coherence and shifts in the archaeological record, which presumably could correspond to new ecological conditions to which humans responded by their behavioural adaptation during the MIS3 in this region.

Key words: Bacho Kiro Cave, Early Upper Palaeolithic, Initial Upper Palaeolithic, Kozarnika cave, MIS 3, Temnata cave, Transition Middle to Upper Palaeolithic.

Palaeoenvironmental changes in the early Gravettian and the Last Glacial Maximum - a comparison of species composition, food webs, and resource use from Lower Austria

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We present osteoarchaeological and bone collagen stable isotope data of Early Gravettian assemblages (approx. 33 – 29 ka cal BP) from the sites of Krems-Hundssteig, Krems-Wachtberg, and Langenlois, in comparison to Kammern-Grubgraben (Last Glacial Maximum, approx. 24 – 19 ka cal BP). Faunal composition changes substantially over time, from mammoth-dominated assemblages to a dominance of ruminants such as reindeer, horse, and ibex. Additionally, the greater species diversity in the LGM demonstrates a change in the environment or subsistence strategies.

At the Early Gravettian sites, herbivores exhibit $\delta^{15}N$ values of bone collagen of 5.2 ‰ on average. In agreement with previously published data, mammoths had significantly higher $\delta^{15}N$ values (mean: 8.2 ‰). Migration, differences in habitat use, feeding habits and/or physiological factors might be the reason for this anomaly. Among other herbivores, niche partitioning in carbon isotopes between horse and hare (mean: -20.6 ‰) on the one, and reindeer and ibex (mean: -19.3 ‰) on the other side indicate dietary preferences or differential habitat use, with higher $\delta^{13}C$ values being associated with drier ecosystems.

At the LGM site, almost all herbivores (reindeer, ibex, horse, bison, hare, mammoth) show similar $\delta^{15}N$ composition. However, values are generally lower (mean value: 2.5 ‰) than at the Early Gravettian sites. As expected, $\delta^{15}N$ values of carnivores (wolf, polar fox, red fox, wolverine) are at least one trophic level higher than herbivores. Similar to the Gravettian sites, carbon isotopes exhibit a clustering in herbivores, however, mammoth $\delta^{13}C$ values spread between the two herbivorous groups. Wolf and wolverine tend to have higher $\delta^{13}C$ values in both time periods indicating predominant foraging on reindeer or ibex.

In conclusion, our results show a trophic partitioning typical for a tundra steppe-like ecosystem. The study also demonstrates a shift in both, the species composition, and the nitrogen isotope baseline between the Early Gravettian and the LGM. We also show that the exceptionally high $\delta^{15}N$ values for mammoth in the Early Gravettian are not reflected at the LGM site. Moreover, carbon isotopes allow inferring habitat differentiation between herbivores which may give important indications regarding preferred hunting grounds during the Gravettian and LGM.

Characteristics of the Upper Paleolithic lithic assemblages from the Piatra Neamț sites (eastern Carpathians, Romania)

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One of the richest areas of Paleolithic findings in Romania is the Bistrița valley, which stands out through a remarkable density of sites (approximately 20 settlements) located on the eastern mountain rim of the Carpathians, in a completely different environment from the region of significant concentrations of Paleolithic sites in Eastern Europe (e.g. Kostenki-Borchevo region). The distribution of the sites is not uniform, with four distinct areas, unevenly researched: the Ceahlău basin, with the largest number of settlements; Bicaz, with an impressive number of lithic materials discovered over time; the Piatra Neamț area, where there are three sites, of which Poiana Cireșului remains a key settlement for the eastern Carpathians, preserving a long chronostratigraphic succession as well as the oldest Upper Paleolithic occupations in this area; and the lower basin of the Bistrița, with two sites, Buda and Lespezi.
Benefiting from recent research, the three sites from Piatra Neamț have a good chronology, several different Paleolithic occupations spanning a long period (between 20 ka cal. BP and 40 ka cal BP) and, unlike most settlements in the east of the Carpathians, the deposits preserve the organic materials very well. To date, eight occupations have been better investigated at these sites, with a chronology between 20 and 30 ka cal BP, therefore overlapping almost the entire Gravettian and Early Epigravettian periods. Being located in the same region, at a very short distance from each other, these sites provide a good opportunity to understand the technical behavior and the exploitation of the similar environment by different Paleolithic communities over a long period of time. Here we present the lithic assemblage from the Piatra Neamț sites, along with the main cultural characteristics of each occupation. Preliminary analysis indicated significant differences between most of the occupations in this area, including in terms of the management of mineral resources, most likely a response to climate change and the environment.

Finding the missing piece but struggling to finish the puzzle: combining off-site and on-site geoarchaeological research in the Swabian Jura (SW Germany) to tackle population dynamics during the LGM

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The presence of Palaeolithic foragers in Central Europe during the Last Glacial Maximum (LGM; 25-20 ka cal BP) remains a fascinating and debated research topic, with important implications for the study of the subsequent Magdalenian colonisation of Europe. In Palaeolithic archaeology, phases of de-population are usually inferred from gaps in regional archaeological records. These gaps, however, might also reflect taphonomic processes active at a regional scale, making the integration of on-site and off-site analyses pivotal to tease apart forager behaviours from post-depositional disturbances.

Caves and rockshelters situated in the Ach and Lone valleys (Swabian Jura, SW Germany), show almost no materials and sediments dating between the Gravettian (35-30 ka cal BP) and Magdalenian (17-14 ka cal BP) occupations. This hiatus has been generally interpreted as a phase of human depopulation associated with deteriorating environments during the LGM. With our previous works on linking cave stratigraphic data with open-air geomorphological archives in the Swabian Jura, we proposed an alternative interpretation. We argued that this gap does not necessarily correspond to a phase of depopulation but rather reflects a phase of cave erosion, which was triggered by regional landscape changes. In more recent years, archaeological excavations at the rockshelter of Langmahdhalde, in the Lone Valley, unearthed a 2 m thick sequence composed of sterile loess, dating between ca. 27 and 17 ka cal BP. This discovery is ground-breaking, as it represents the best evidence of deposits dating to the LGM so far unearthed from archaeological sites located in the Swabian Jura. This finding poses new challenging questions: (i) Why erosional processes did not impact on the preservation of LGM deposits at Langmahdhalde? (ii) Are these sterile deposits the final proof that the Swabian Jura was indeed abandoned during the LGM?

To answer these questions, we will present our preliminary results from a new research project, which aims to link off-site geophysical, coring, micromorphological, and luminescence dating with on-site micromorphological, radiocarbon, and microfaunal results from Langmahdhalde. This work gives us the opportunity to showcase the complex interaction between human behaviour, site formation processes, and regional geomorphology in the Swabian Jura during the LGM.

Krotova, Oleksandra (Institute of Archaeology of NAS, Ukraine) Upper Palaeolithic hunter-gatherers' adaptation during the Last Glacial Maximum in Southern Ukraine

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The main results of Amvrosievka site (South-Eastern Ukraine) complex research guided under the author's direction during about the last thirty years are analyzed in the report. The complex consisting of a base camp and bison kill site situated nearby represents a unique Late Pleistocene locality that offers a great deal of information about the Late Pleistocene hunter adaptations.

The paleogeographers argued that the horizon with the densest concentration of cultural remains of the campsite lie in the gray-brown sandy loam below the Holocene horizon. Under this layers are a brownish loam – the Late Pleistocene soil, predating occupation of the camp. The site is dated on the basis of 16 radiocarbon dates from the bone bed (14) and camp (2). Most of the dates are closely related to the value an average of 19,000–18,000 uncal 14C BP.

The bone bed was the kill site for some hunting operations and the place of primary butchering of hunting bag. Secondary carcass butchering, bone processing for making tools, skin processing, and manufacturing of the variety objects also took place at the camp.

During the Late Glacial Maximum (LGM) in territory of the south of continental Ukraine prevailed cold and an arid climate and open landscapes with steppe vegetation. Paleontologists consider that this period was marked by a high density of large herbivores, first of all, the bison.

The rests of a bison averaged 88% of faunal remains in the collections of large herbivores in some main epigravettian sites – Amvrosievka, Anetivka 2 and Velyka Akarzha.

From the ethnographic model, the high density of prey formed the basis of a regular driving seasonal hunting and storage strategy that gave the large hunter groups (to a few communities) an opportunity to live near food storage places during the whole season. Thus, the adaptation of hunter groups in this period are defined by specialized bison hunting, predominance of a logistical mobility in life-style, and a relatively stable social relationship.

Residue analysis for the reconstruction of Late Glacial hunting activities: new data from the Epigravettian series of Grotta della Cala (Campania, southern Italy)

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Residue analysis is one of the most promising approaches in dealing with the reconstruction of past human activities, through the identification of ephemeral traces of organic substances by means of cutting-edge techniques capable to characterise ever-smaller samples. In this frame, the use of spectroscopic techniques has proven to be a valuable tool for residue identification, as well as the application of multi-techniques protocols investigating the sample on different levels (morphological, elemental, molecular, structural). In this presentation, the results of the application of residue analysis on a set of more than twenty backed tools retrieved in the entire Epigravettian series of Grotta della Cala (Campania, southern Italy) are discussed and compared throughout the sequence of this technocomplex, which is composed by eight stratigraphic units ascribed to both the evolved (layers P, N, O and M) and final (layers I, L, H and G) phases. From layers N, M and H a series of radiometric dates were obtained which are coherent with the stratigraphic sequence (N: 20826-18819, M: 18978-16863, and H: 14173-13600, 14842-14096, 14226-13598, cal BP - 68,3 %). Over this wide span of time, as is well known, human groups have often faced harsh climatic conditions and rapid environmental turnovers, adapting to the changing surroundings in sometimes unexpected ways. In this frame, the overall analysis of residues coming from the Epigravettian series of Grotta della Cala is meant to provide compelling insights into hunter-gatherers' exploitation of natural resources, with a particular focus on the use of lithic artefacts connected with hunting activities. The workflow applied in the present communication includes complementary techniques like 3D digital microscopy, Fourier Transform InfraRed microscopy, Low Energy X-Ray Fluorescence microscopy and Particle Induced X-ray Emission, which have been already successfully combined by our group in past works to achieve a complete chemical characterisation of each residue.

Technology and subsistence strategies of the Epigravettian groups in southern Italy: new data from layer 9c of Grotta Paglicci (Apulia) and layer O of Grotta della Cala (Campania)

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The Epigravettian is an Upper Palaeolithic technocomplex dated between c. 26-25 ka and 11.9-11.6 ka cal BP, which is well attested in Italy. It developed from Last Glacial Maximum (LGM) to the final phases of the Late Glacial (LG), in a period of remarkable changes in environmental conditions. During the LGM, due to adverse climatic conditions, Epigravettian sites are mainly clustered in 'refuges' such as the southern part of Italy. Our study focuses on the Evolved Epigravettian (c. 16,000 to 15,000/14,500 uncal. BP) of this region in order to achieve new data on possible analogies or dissimilarities in technology and subsistence strategies implemented by hunter-gathers in different environmental conditions. Therefore, we analysed two lithic assemblages respectively on the Adriatic and the Tyrrhenian side of the Italian Peninsula: layer 9c (18,002–18,956 Cal BP) of Grotta Paglicci (Apulia) and layer O of Grotta della Cala (Campania), which can be dated around 21-20 ka cal. BP, based on the date obtained for the immediately overlying layer N (20,826-18,819 cal. BP - 68,3 %).

Human behaviour and environmental change in the upper complex of the Grotta Romanelli (Lecce, southern Italy)

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Grotta Romanelli is a reference site in the Mediterranean area for the reconstruction of both cultural aspects and environmental changes from the Middle Pleistocene to the onset of the Holocene. Excavations, begun in 1914 by Gian Alberto Blanc and continued intermittently until the 1970s, have revealed a well-articulated stratigraphic sequence. The uppermost part of infilling deposit has provided human remains and thousands of vertebrate remains, lithics and mobiliary art that helped to define the archaeological and paleoecological specifics of the final phase of the Upper Palaeolithic.

When research resumed in 2015, the aim was to update and to investigate in more detail the chrono-cultural framework in the upper complex focusing on the reconstruction of the organisational strategies of the human groups in response to environmental changes, both in the structuring of activities within the site and in the management of the surrounding territory. The current work analyses what has emerged from the recent excavations, specifically considering the studies of those classes of material most represented in the archaeological record of the upper complex.

The analysis of the deposit is based on stratigraphic excavation with integrated computerised data documentation and archiving, this approach incrementing the precision and speed of interpretation and facilitating correlation between spatial data and those arising from the analysis of microfauna, zooarchaeological data and lithic tools.

Within this analytical structure, the study of the small mammals allows us to define the climatic/environmental phases and to put them in relation with the trophic strategies of humans during the phase in which the cave was occupied. The zooarchaeological analysis of the macrofauna and the study of the techniques of lithic production contribute substantially to the reconstruction of human behaviour and spatial use of the cave. The zooarchaeological analysis of the faunal remains provides detailed information on prey exploitation and adds new data regarding the seasonal occupation of the site. Moreover, the study of lithic production shows the systematic introduction of non-local lithotypes and a diachronic tendency towards the creation of products that could be linked to hunting strategies.

Session 88: Human-environmental Interactions Along the Ancient Silk Roads

Ancient hydro-geomorphy in Dunhuang region and the water conservancy facility “HanSaiQiang” before 2000 years

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Dunhuang was one of the most important sites on the Silk Road. The Shazhou, Yangguan and Yumenguan under its jurisdiction were the famous cities and passes in the Han dynasty. Between the Shazhou oasis along the Danghe River and the Yangguan oasis on the east bank of the Xitugou river, there is a unique relic of the Han Dynasty (~208BC to ~219AD), ‘HanSaiQiang’(HSQ), that means a wall or dam for blocking in Han dynasty. It is 3-5m wide and 1~1.5m high, extending from Danghe Reservoir in the east to Shazaodun beacon tower in the west, with a total length of about 16km. It is a gravel ridge made entirely of gravel on the Gobi Desert, without any sedimentary structure. The role of the HSQ has always been a mystery, and it was guessed to be use for flood protection, or as the sign of the ancient road.

The landform landscape of Shazhou-Yumenguan area shows that the whole area is the Danghe River proluvial fan which east boundary is the current Danghe River and the west boundary is Yangguan-Linchangcun-Erduncun river net. During the Han dynasty, Danghe River floods once rampant in this vast area. The HSQ wall completely isolated the flood northward flowing in the section of the proluvial fan, and forcing the eastern flood into the Danghe river in east to nourish Shazhou oasis, western flood flows to Yangguan, Linchangcun village, Erduncun village to form Yangguan-Erduncun village oasis belt, providing guarantee for the Yangguan-Yumenguan Pass traffic artery. Therefore, it is concluded that the HSQ Wall is a important water conservancy project implemented by the ancients of the Han Dynasty, aiming to completely change the landscape pattern of the Dunhuang area and create an oasis environment conducive to reclamation and defense.

The emergence of rice and millet farming in the Zang-Yi Corridor of southwest China dates back to 5000 years ago

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The Zang-Yi Corridor is of pivotal significance for the interactions between northwest China, southwest China, and mainland Southeast Asia. It has been hypothesized that the formation of mixed farming in this region and its surrounding areas was based on multiple waves of crop dispersal, with foxtail millet and broomcorn millet arriving first from northwest China around 5300 cal. BP and rice from middle Yangtze valley after 4700 cal. BP. Based on the systematic sampling and direct dating conducted at the Guijiabao site, Sichuan Province, this study demonstrates that by no later than 5000 cal. BP, mixed farming had already emerged in the south part of Zang-Yi corridor, which was much earlier than expected before. With this new evidence, it is argued that the transformation into farming in Southwest China was based on the dispersal of a crop package comprising foxtail millet, broomcorn millet, and rice instead of different waves of introduction. A further comparison of all archaeobotanical data in this region revealed that crop patterns varied significantly between different sites because of their diverse environmental conditions.

Nearly 2500 years of precipitation change in the core of Arid Central Asia and its potential impact on Silk Road civilization evolution

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The ecological environment in Arid Central Asia (ACA) is fragile and sensitive to global climate change. However, there is a lack of accurate quantitative precipitation reconstruction in the study area, which limits the understanding of regional water-heat distribution, and also fails to obtain an in-depth understanding of the relationship between climate change and the Silk Road civilization. In this study, pollen analysis of Sasikul lake on the Pamir Plateau was performed within the framework of six AMS^{14}C ages chronologies and the precipitation change in recent 2500 years was quantitatively reconstructed. Among them, drought-tolerant Amaranthaceae pollen during the MWP reached the highest in the study section, with an average annual precipitation of 115 mm, about 15% lower than modern precipitation, and the climate was relatively dry. During the LIA, *Artemisia*, *Picea* and *Abies* had higher pollen content, with an average annual precipitation of 160 mm (up to 210 mm), about 20% higher than the modern precipitation, and the climate was cold and humid. On this basis, we explore the possible influence of climate change on the evolution of Silk Road civilizations during the historical period, combining regional high-quality temperature records and archaeological data. We believe that the temperature conditions in the water-heat distribution have the most important impact on human activities and the evolution of the Silk Road civilization in ACA. In the Sui-Tang Dynasties, under the warm climate, the melting water of ice-snow increased significantly, the oasis area expanded and the Silk Road civilization flourished and developed; while in the Ming dynasty, the cold and dry climate conditions and the lack of fresh water input led to the reduction of the oasis area, the significant decline of the Silk Road civilization.

Middle Holocene landscape change, climate change and human adaptation in mountainous Central Asia

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The archaeological site of Chap in Kyrgyzstan has been identified as an important centre of prehistoric agriculture in the central Tien Shan. A large archaeobotanical assemblage indicates two periods of intensive occupation and cultivation, ranging ca. 4400-4000 BP and ca. 3000-2800 BP. The occupational layers at the site are separated by thick to very thick bedded fine-grained sediments, absent any cultural materials. Deposition of these sediments appears contemporary with regional climate deterioration, and these conditions have been raised as possible drivers of the ca. 1000-year gap in occupation of the site. This presentation explores the environmental context of human settlement and abandonment of the site through palaeoenvironmental proxies from these sediment layers (including pollen, magnetic and sediment size data). From the data we interpret indicators for anthropogenic and natural processes driving landscape change around the site. We compare these local-scale data with other on-site archaeobotanical remains, and regional-scale palaeoclimate records and archaeological settlement patterns to better understand past human responses to environmental and climate change in mountainous Central Asia.

First paleoclimate calibrations for pollen transfer functions and biomarkers (brGDGTs) covering the Caspian sea to Arid Central Asian area.

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Accurate climate reconstructions are important to better investigate the Holocene climate changes mainly because this period appears to be a smooth continuity to the current and the future climate warming and also because the human-societies and climate systems interactions begin from this period to be undeniably ravelled. In this context, an important issue address the understanding of the links between proxies (eg pollen and molecular biomarkers) and environmental forcing (climate…) through accurate calibrations on modern samples. Even if this environment-proxy causal relation has to be studied in a global biogeographical context (flowering plants producing pollen and bacteria or archaea producing biomarkers as Glycerol Dialkyl Glyceryl Tetraethers depend on vegetation, geological bedrock and soils as well as climate), some geographical areas are poorly documented. Among them, the Caucasus lowlands of Azerbaijan and the Touran basin to Pamir-Alay piedmonts and mountains of Uzbekistan and Tajikistan have never been investigated.

In this study, we have collected and analysed new modern samples for pollen and GDGTs from Azerbaijan, Uzbekistan and Tajikistan. Calibrations are then established. The pollen samples have been compared to vegetation *relevés* to better understand the vegetation-pollen rain relation, and then, some transfer function methods (MAT and WAPLS) or machine-learning methods (BRT and RF) have been applied to reconstruct climate parameters from pollen assemblages. A particular focus has been carried on local condition for each surface samples: surrounding vegetation, biome extraction, soil description, sample type (top-core, moss polster or soil), in order to unravel the potential local bias in climate reconstruction. Finally, for both proxies, the discussed results and calibrations will be tested on two paleo-records from lakes Fazilman and Tuya (Uzbekistan).

This study highlight the difficulties raised by the special conditions of these extreme environments (arid to semi-arid context, impact of soil pH, salinity and gypsum content) on pollen and brGDGTs vs. climate calibrations.

Connecting Dots: Human Migration and Trade in Trans-Himalayas based on archaeological evidences in Spiti valley

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The Hind Kush, the Pamir, the Karakoram, and the Large Himalayas are among the great mountain ranges that make up the western Himalayan region, which stretches from Chitral in the far west to the Uttarakhand Himalaya in the east. Behind it is the Plateau of Tibet, which is connected to the Himalayas through various passes spread across these ranges. The main hub of significant local and long-distance trade networks is located in Ladakh, which is on the upper Indus. Indeed, it is the intersection of several trade routes from Kashmir, Punjab, and Yarkand. At Gartok, the Leh-Lhasa route is joined by many passes from the Uttarakhand Himalaya and passes from Lahul and Spiti in Himachal Pradesh. From the way the western Himalayas look, it is clear that trade with China and Central Asia was important for the area's economy to grow.

The trans-Himalayan region of India has been archaeologically explored earlier in Niti Valley, Uttarakhand, and Kinnaur, Himachal Pradesh shows many interesting aspects of the lives of its inhabitants in these harsh and rugged climatic conditions. The artifacts found at different sites in the Spiti Valley show that a highly developed culture grew and thrived in the first millennium BCE, and that this culture lasted until the historical period. Even though they lived in a remote part of the Trans-Himalayas, you couldn't call them primitive or nomadic. So, the research in the higher Trans-Himalayan region became important because it helped fill a gap in India's higher Himalayan prehistoric archaeology. From a broader point of view, the study has given us new ways to look into other important topics, such as rock art, burial culture and its spread, ceramic traditions, metallurgy, shell beads, and technological advances. This study is an attempt to gather evidence that the Himalayas were never a barrier, as believed. Instead, through its passes, people were well connected through trade and were moving to the faraway places of mainland India and central Asia.

The Entanglement of Landscape: Fire, Climate, and Agro-Pastoralism in the Bronze and Iron Age South Caucasus

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This paper investigates how the different social and political structures in Bronze and Iron Age Armenia shaped the surrounding steppe landscape through their agro-pastoral practices. We utilized a series of sediment cores from an altitudinal transect from around Mount Aragats, Armenia in conjunction with multiple biological and geochemical proxies (pollen, non-pollen palynomorphs, XRF, brGDGTs) and the archaeological record to untangle drivers of landscape change. This novel approach integrates multiple lines of evidence in order to understand the complexity of the entanglements of climate, fire, agro-pastoralism, and vegetation in this mountain steppe landscape.

In this paper we focus on the pollen and macro-charcoal results from two sediment cores. One higher in the foothills, published in Cromartie et al. (2020), and a new record located in the valley. We find the markers of human activity corresponds with Early Bronze Age Kura-Araxes expansion of cereal agriculture into this highland region. This is followed by a decline in these markers in the Middle Bronze Age when there is a shift away from permanent settlements and increases in mobile pastoralism. Human indicators of agro-pastoralism land-usage return as communities return to practice settled agriculture from the Late Bronze Age through the Iron Age. Human landscape usage is primarily isolated to the core site in the valley through most of the record, but this changes during the Iron Age when shifts in political structure may have driven communities to utilize wetlands higher in altitude. Macro-charcoal analysis across all cores records a similar fire history which appears to be driven by climate until the last 2000 years but shifts in vegetation in the previous periods suggests humans contributed to declines in the natural fire regime. Overall, our records show that even within a small geographical area, human communities unevenly utilized the landscape and the differing social-political contexts influenced these changes. We highlight that social-political and agro-pastoral change needs to be considered when reconstructing landscape usage and predicting future change.

Session 89: Cenozoic sea-level indicators and ice sheet constraints to global sea-level change

Modeling the Last Interglacial notch formation in Orosei, Sardinia: A Monte Carlo approach

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Imprints that the sea level left during the Last Interglacial (127-116ka BP) are carved on the limestone cliffs of the Orosei Gulf (Sardinia, Italy). Along at least 40 km of almost vertical cliffs and located up to ten meters above modern sea level, several workers described it as a relic tidal notch (Antonioli et al. 2018). Here, we mapped the best-preserved part of this notch using Structure from Motion - Multi-View Stereo (SfM-MVS) techniques, that reveal the details of the hitherto described “double notch” geometry, culminating with an indentation at 10.5m above mean sea level. Although its geometry is laterally constant, the notch's depth differs by 3m, while its base is ranging from well-formed to locally absent, possibly due to local factors that appear to control the notch morphology. In our study, we use a numerical model of tidal notch formation (based on Schneiderwind et al. 2017) that we run using a Monte Carlo approach, with varying erosion rate, bedrock slope, tidal range, tectonics, and relative sea-level (RSL). We discuss under which parameters we obtain the best-matching results between modeled and observed notch geometry. We surmise that this kind of inverted approach might give new insights into classic Last Interglacial relic landforms such as the Orosei tidal notch.

Constraining sea level oscillations in the Last Interglacial by modeling fossil coral reefs

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Understanding past sea-level (SL) oscillations is essential to gauge the future patterns of SL rise, in response to warmer climate conditions. Thanks to the good preservation and dating of fossil outcrops, the Last Interglacial (LIG; ~122 ka ago) is one of the best climate analogs to study the possibility of abrupt SL changes within an interglacial. The existence and magnitude of possible intra-LIG SL oscillations is a hotly debated topic. Indeed, some LIG coastal stratigraphic sequences, especially those stemming from coral reef terraces (CRTs), are characterized by abrupt shifts in geological facies or double/multiple stepped stratigraphies, which were hitherto interpreted as proxies for abrupt SL oscillations. To investigate whether these geological formations have an eustatic origin, we focused on modeling the processes and SL scenarios that may contribute to build such reef stratigraphies. For this purpose, we used two models: DionisosFlow software (i.e., a forward stratigraphic model) and the code of Pastier et al. (2019; Geochemistry, Geophysics, Geosystems, 20(8); i.e., a kinematic model based on reef morphology). In our work, we first calibrated the CRT morphogenesis parameters (e.g., carbonate production/reef growth; sedimentation; marine erosion; rock foundation geometry, etc.) based on global reef observations. Then, we tested different SL scenarios (e.g., a stable SL highstand, a stable SL followed by a rapid jump, a double peak SL highstand, etc.). Finally, we compared modeled and observed stratigraphies, and investigated which parameter set, processes and SL scenario are most consistent with observations of double/multiple-stepped reef stratigraphies at different sites globally. Our results highlight that the morphology of CRT sequences provides fundamental observations to unravel past SL, including the possible intra-LIG SL oscillations.

DATED-2: An updated ice-extent chronology for the last Eurasian ice sheet complex, 40-10 ka

Dr. Anna L.C. Hughes [1]***, Dr. Jo Brendryen*** [2]***, Dr. Richard Gyllencreutz*** [3]***, Dr. Evan Gowan*** [4]***, Dr. Jan Mangerud*** [2]***, Dr. John Inge Svendsen*** [2]

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DATED-1 comprised a fully-documented empirical reconstruction of the changing extent of the last Eurasian ice sheets 40-10 ka (at 1000-year resolution after 25 ka) based on a geological-glaciological assessment of all relevant chronological data (n=5477 dates). All uncertainties within the underlying data are synthesised and expressed in terms of distance; deviation between maximum and minimum limits, and their relative proximity to the extent considered 'most-credible', indicates the degree of uncertainty along the ice margin for each 1000-year time-slice. Explicitly representing all uncertainties in this way provides a straightforward means to compare geological data with results from numerical modelling of past ice extent. Our process created an archive of published dates (and associated data necessary for their interpretation, quality, and recalculation) relating to the build-up and retreat of the British-Irish, Scandinavian and Svalbard-Barents Kara seas ice sheets. Both the time-slice reconstructions and underlying chronological dataset are available via the online data repository PANGAEA. However, new empirical geological data and interpretations are generated almost continually and valuable syntheses such as this run the risk of being frozen-in-time and losing their relevance if not maintained and updated to reflect the latest observations. A decade on from the DATED-1 census of 1 January 2013 the volume of data has grown significantly (>5000 additional dates, >1000 additional sites), and in-tandem with methodological developments in dating procedures and calibrations. Here, we present the second-generation chronological synthesis, DATED-2, which brings the chronological dataset and time-slice reconstructions for the Eurasian ice sheets up-to-date; including all new chronological information published up to 1 January 2023. We highlight the main changes required to satisfy new dates, present a new calculation of the evolution in ice sheet volume and timing of sea level contributions from the Eurasian ice sheets, and discuss implications for, and obstacles to, constraining the timing of ice sheet build-up and demise using empirical geological data.

New dating and elevations constrain the LIG eustatic sea level in south-west Madagascar

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Global mean sea level (GMSL) rise is one of the most obvious manifestations of ongoing climate change with major consequences for densely populated coastal regions and islands. However, predictions about the amplitude of the GMSL rise in the future and how it will vary across the ocean are still not accurate enough. To improve the long-term estimates of future sea-level rise, geological records can help to constrain the polar ice-sheet sensitivity to warmer climates. Toward that purpose, the Last Interglacial (LIG, Marine Isotopic Stage 5e, 125 ka) when global mean surface temperature was 0.5°C–1.0°C warmer, and the sea level would have reached elevation of about 5 to 10 m above present, is one of the most appropriate target.

While many sites in West Indian Ocean (WIO) are known to have preserved LIG sea-level indicators, there are far less recent and precise studies dedicated to paleo sea level in WIO in comparison to the Pacific and Atlantic Oceans. Thanks to technical advancements in both survey and geochronology, we aimed to achieve precise paleo RSL reconstructions at the site of Lembetabe, southwest Madagascar, where a fossil reef was first described by the researcher René Battistini more than 50 years ago.

Based on 16 new U-Th ages and a cartography of the fossil reef platform using differential GNSS and drone photogrammetry, we estimate that paleo relative sea level at Lembetabe reached about 3.4 ± 1.4 m above modern between 129 ka and 115 ka. Once corrected for glacial isostatic adjustment, our data suggest that the paleo relative sea level did not exceeded 3 m above modern. Only slight crustal subsidence (that might be related to active faulting) would reconcile our estimate with the 5-10 m often-cited LIG range.

MIS 5 beachrock deposits exposed along the Ujeon beach, Jeungdo, in the southwestern coast of Korea: implications for high relative sea-levels during the last interglacial

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Beachrocks, lithified coastal deposits, have been often used as a powerful marker of relative sea levels like the coral-based records. They underwent almost no post-depositional compaction, thereby recording the position of the shoreline. In this regard, we have examined beachrocks exposed along the coastal dune scarps in the Ujeon beach in order to reconstruct the sea level history during the late Quaternary in the Korean coastal seas. For these purposes, two sections from dune scarps were trenched and four vibracores were taken along the beach-dune transect lines. OSL (optically stimulated luminescene) and ^{14}C-AMS (accelerator mass spectrometry) radiocarbon datings were conducted to determine the ages of the beachrocks, tidal and coastal dune deposits. Additionally, grain sizes and magnetic susceptibility were measured from the trench sections. Sedimentary facies loggings were carried out based on the lithology, structures, colors and biogenic activities. The results show that the Ujeon beach-dune deposits are classified into six major facies types: (1) MIS 5 tidal muds, (2) MIS 5 beachrocks, (3) MIS 4 paleosols, (4) mid-Holocene tidal muds, (5) late Holocene dune sands, and (6) present-day beach sands in stratigraphically ascending order. Of these, beachrock deposits are characterized by laminated, reddish yellow, coarse sands, directly overlying semi-consolidated, older tidal muds dated to MIS 5e. More than 1 m thick of beachrocks display subhorizontal laminations alternating dark and light laminae. Seven OSL samples from beachrocks of two trench sections were dated between 140 and 83 ka, corresponding to MIS 5. They occur ca. 1 m above mean high water level. Considering high elevation of beachrocks and relatively stable tectonic activities from the previous works in the west coast of Korean peninsula, we suggest higher relative sea levels during MIS 5 than those in the Holocene interglacial. This study thus underlines the OSL dated MIS 5 beachrock deposits along the Jeungdo tidal shore in Korea, here documented for the first time in the Yellow Sea.

Constraining the timing and elevation of penultimate interglacial sea levels using submerged speleothems from the Bahamas

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Late Quaternary glacial cycles occur at intervals of approximately 100,000 years. They oscillate between warm interglacial periods, with reduced continental ice volume and global sea level comparable to today, and cool glacial periods, with expanded continental ice sheets and sea levels as much as 100 m lower. However, the timing, magnitude, and evolution of each glacial cycle differs and cannot be explained simply by orbital forcing alone. Coastal cave deposits (speleothems) from tectonically-stable islands can provide valuable evidence to constrain the timing and amplitude of sea-level change and complement the existing constraints from fossil coral and marine sedimentary evidence. Speleothems, which form from the degassing of drip waters in caves, must have been subaerially exposed during periods of lower sea levels to allow calcite precipitation, and hiatuses in growth can represent periods of submergence by rising sea levels. Precise U-Th ages for calcite immediately before and after hiatuses in growth can thus be used to “bracket” the timing of sea-level rise and fall during interglacial periods.

We present a new relative sea level (RSL) reconstruction for the penultimate interglacial (Marine Isotope Stage 7), using speleothems from the submerged blue hole Sagittarius Cave, Grand Bahama. The flowstone samples used in our study grew between 13-21 m below present sea level, with multiple phases of growth present in each sample. Detrital thorium contamination poses a challenge for dating speleothems from the Bahamas because the ($^{230}Th/^{232}Th$) activity ratio of drip waters can be an order of magnitude higher than bulk continental crust. Nonetheless, U-series ages demonstrate a hiatus separating two of the growth phases that correspond to MIS 8 and 6. The hiatus contains a thin layer of red, Fe-rich sediment, similar to that found on surfaces below the freshwater mixing zone in submerged caves of the Bahamas today. We interpret this as evidence that the flowstones were submerged below sea level during MIS-7. We will utilize glacial isostatic adjustment modelling to compare our sea level constraints to other RSL records from the penultimate interglacial (e.g., Argentarola Cave, Italy) and draw inferences about global mean sea level change during this period.

Sea-level changes and the closure of Neo-Tethys seaway during the Middle Miocene in the Naga Hills, Indo-Myanmar Range

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Abstract

Miocene planktonic foraminifers occur in shale intercalated with thinly bedded siltstone and sandstone of the Surma Group in the foothills of the Naga Schuppen Belt of the Indo-Myanmar Range. These are the first clearly imaged middle Miocene foraminifera from the Surma Group of the Naga Hills. This new M5-M6 assemblage from the upper Bhuban Formation correlates with the uppermost Burdigalian to Langhian age (16-14 Ma). The biostratigraphy, paleoenvironment, sea-level change and paleogeography of the assemblage is significant. It provides a basis for widespread regional and global correlation constraining timing of Neo-Tethys seaway closure. Results indicate that remnants of the Neo-Tethys seaway endured in eastern parts of the India-Eurasia collision zone until the Miocene. This contrasts with the western and Tibetan Himalaya where Neo-Tethys disappeared well before the Miocene. The finding is significant in conjunction with global sea-level change.

Session 90: Ancient DNA from Quaternary and Archaeological Sediments

A sampling strategy to maximize the yield of ancient DNA from archaeological sediments

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Archeological sediments represent a nearly infinite source of ancient DNA (aDNA), which, if fully exploited, may revolutionize palaeogenetic research. Current approaches of aDNA analysis from sediments rely on core sampling or loose sediment samples from exposed stratigraphic profiles. Although quite effective, these approaches do not allow us to predict which features of the sediment are most likely to preserve aDNA. A recent study has shown that impregnated blocks of undisturbed sediments, collected for micromorphological analysis, are excellent source of aDNA. Microsampling of blocks from Denisova Cave revealed that mammalian aDNA is not uniformly distributed in the sediment but rather concentrated in small particles, emphasizing the need for further exploration of high-precision sampling. This study also showed that sampling from micromorphology blocks may improve our access to aDNA from rare taxa and single individuals, e.g., hominins, as it reduces the “noise” of high taxonomic diversity encountered when analyzing loose sediment samples. However, micromorphology block samples are unsuitable for routine aDNA screening of archaeological sediments. Here, we propose an approach that combines sampling of loose sediments alongside micromorphology blocks to maximize the recovery of DNA from taxa of interest, while allowing for accurate micro-contextualization of the genetic signal. The loose samples are used for initial broad screening to identify promising areas for aDNA recovery within an archaeological site . The micromorphology blocks from these areas are then used to contextualize the genetic signals and maximize the yield of aDNA from specific taxa through targeted microsampling. We applied this approach to sediments from high altitude tropical environments at three late Pleistocene to Holocene sites in Malawi (eastern Africa), one of which has produced the oldest human DNA recovered from the continent to date. Screening of these samples for aDNA will provide information about the feasibility of this approach in under-sampled geographical regions with challenging DNA preservation conditions, such as the tropics.

Mesolithic-Neolithic Environmental Reconstruction from sedaDNA: Data from the Stonehenge Area and Suffolk

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The extraction and analysis of sedimentary ancient DNA (sedaDNA) is revolutionising palaeoecology and Quaternary science. It is also making an increasing contribution to environmental archaeology from both off-site and on-site contexts. SedaDNA analysis of two prehistoric archaeological sites in the UK- Blick Mead, Wiltshire and Martlesham, Suffolk, highlight the potential of the method for reconstructing plant and animal communities associated with wetland archaeological activity. At Blick Mead, where there is Late Mesolithic occupation of a floodplain terrace edge for the hunting of aurochs, the sedaDNA reveals open ground conditions typical of a large clearing within the regional forest. At Martlesham, sedaDNA from four domestic mammals: cow, sheep, pig and goat, reveals Neolithic pastoral activity in enclosed woodland (forest farming) surrounding a palaeochannel with trackways. Together, the two sites indicate that sedaDNA can prove a valuable new data on the landscape change and human activity during the critical Mesolithic-Neolithic transition.

Impact of climate and domesticated mammals on Holocene plant richness in the European Alps revealed by sedaDNA

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Disentangling the effect of climate change and human activities on vegetation richness is essential to understand and manage ongoing drivers of change. In this study, we reconstruct plant diversity and the distributions of domesticated mammals at 14 lake sites across the Alps during the Holocene, with the aim to explore the relative contribution of climate and land use in shaping the present vegetation. We produce the largest lake sedaDNA dataset of southern Europe, consisting of plant and mammal metabarcoding applied to 705 sediment samples. To disentangle the effects of climate from human impact on vegetation, we studied the influence of temperature, precipitation and domesticated mammals on plant species composition. In total, 747 plant taxa were identified, 43% at species level. Most lakes showed a slowly increasing trend in plant richness since the Holocene. Some lakes have a notable rise at 5,000 years ago, and on the other hand some lakes showed a strong increase in the last 2,000 years. All lakes showed several shifts in dominant growth form, with periods dominated by tree species alternating with periods dominated by forbs. Domestic mammals were identified at all 14 sites, consisting in sheep, goat, cow and horse. Mammal sedaDNA showed the first presence of domestication in the French Alps by the mid-Holocene, which was dominated by goat and sheep. During the Bronze Age, domesticates spread towards the central and eastern Alps, coinciding with the introduction of cows. To further contextualize our results, we will discuss them in light of the regional archaeological data for each period. Our findings suggest both long-term agropastoral activities and climate contributed to the high plant richness of the ecosystems in the European Alps.
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What else is in the mud? Current status and future potential of environmental DNA in bryophyte research

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Bryophytes are important components of global ecosystems as they influence biogeochemical cycling. The broad geographic ranges and narrow habitat tolerances of most bryophytes make them a suitable group to study the impact of disturbance and climate change on the resilience of northern ecosystems. However, palaeoecological research of bryophytes is largely limited due to their scattered occurrences as macrofossils. To that end, sedimentary ancient DNA (sedaDNA) may provide high resolution taxonomic and occurrence data for bryophytes. Using sedaDNA data from ten lakes covering the time since deglaciation of the Fennoscandian ice sheet to present, we explored temporal diversity of bryophytes and their regional dispersal in relation to different traits. Out of the 77 taxa detected (10% of northern Norway), 42% and 14% were identified to species and genus level respectively, which is better than traditional proxies. Some mosses and liverworts were present already in the earliest samples dated to 16 000 calibrated years before present (cal BP), and the taxonomic richness continuously increased throughout the period in most of the lakes. A short core showed a negative trend for the last 2500 cal BP and two lakes showed non-linear trends. The dispersal ability varied among different orders of bryophytes. Bryophytes that can thrive either in nutrient poor continental acidic soils and tolerate high light irradiance or have no preferences seem to have arrived first after deglaciation. Bryophytes with both sexual and asexual modes of reproductions appeared before those with very common or rare sexual reproductions. Similarly, spore ornamentation seems to have a positive effect on the dispersal of bryophytes. Most importantly, the first appearance time of bryophytes was negatively correlated with spore size, which indicates wind dispersal as an important driver for bryophyte dispersal. We highlight that bryophytes have so far been reported as the by-catch of sedaDNA projects targeting vascular plants and that reference libraries of bryophytes are incomplete as they cover about 57% of bryophytes of northern Norway. Thus, there is a need to develop bryophyte specific markers and expand the reference library to increase detections and fully harness the power of sedaDNA in bryophyte research.

Sedimentary ancient DNA metabarcoding for the recognition of Paleolithic human plant use

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Plants have always played an integral part in human life, as fuel, medicine, food and other uses. However, our knowledge of plants used by prehistoric humans is limited by the rare survival of identifiable plant parts in the archaeological record. The application of sedimentary ancient DNA (sedaDNA) provides unique possibilities to analyse DNA also in the absence of any visible remains. Such analyses have been applied to a variety of sedimentary contexts, including cave sediments. With caves often mitigating the full effects of the elements on organic materials accumulated by humans, animals, and other natural agents, they provide an opportunity to study past human presence, their activities and their environments through DNA analyses.
Here we present the potential of sedaDNA analyses of cave sediments to study past human plant use. By combining sedaDNA metabarcoding with pollen data we obtained a temporal reconstruction of plant assemblages that were available to early humans at Aghitu-3 Cave in the Armenian Highlands. This cave contains a detailed record of human settlement and environmental variability between 39,000 and 24,000 years ago. Our sedaDNA and pollen results reveal a stratification of plant abundance and diversity. DNA preservation reflects periods of occupation, with higher diversity in layers with greater activity. Moreover, low pollen concentrations combined with high sedaDNA abundance indicates that plants may have been brought into the cave by animals or humans. The majority of the recovered plants are useful as food, flavor, medicine, or for technical purposes, demonstrating the potential of the environment around Aghitu-3 Cave to support humans during the Paleolithic. This study represented the first application of plant sedaDNA analysis of cave sediments for the investigation of potential plant use by early humans. We now analyse a number of other cave sites from different regions and time periods to expand our understanding of plant use by prehistoric humans.

Sedimentary DNA can reveal past pelagic copepod population dynamics

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Copepods play a key trophic role as secondary producers in transferring primary production to higher trophic levels such as fish. Copepod production significantly contributes to successful fish recruitment. Despite their importance, knowledge of their dynamics over several decades remains limited due to the difficulty to obtain long-term data series with exhaustive sampling and analysis. However, an understanding of long-term copepod dynamics is urgently required to strive toward better management for sustainable aquatic ecosystems and fish recruitment. Sedimentary DNA (sedDNA) has been developing as a useful tool for reconstructing past plankton dynamics. This study evaluates whether sedDNA targeting the pelagic copepod, *Eodiaptomus japonicus*, in Lake Biwa (Japan) can be an effective tool for elucidating its past population dynamics. We applied a quantitative polymerase chain reaction method targeting the mitochondrial cytochrome c oxidase subunit I gene on two sediment cores and compared the detected sedDNA concentrations with the unique long-term dataset of demographic traits, biomass, specific growth rate, production, subitaneous eggs, and resting eggs of *E. japonicus*. The sedDNA concentration of *E. japonicus* recovered from sediment layers correlated significantly with *in situ* production, biomass, and subitaneous egg production but not with its resting eggs and its specific growth rate. Our results provide evidence for the use of sedDNA as a tracking tool for assessing past copepod production dynamics.

Natural changes and anthropogenic impacts on a Central European lake and its catchment over the past 15,000 years

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Lake Constance is a pre-Alpine oligotrophic water body that has a long history of human occupation. Its rich and well-studied archeological record, with a high density of Neolithic and Bronze age settlements especially around the Gnadensee and Überlinger See sub-basins, testify to an early human impact on the landscape. In the past century, the lake was intensively impacted by human activity leading to a distinct period of eutrophication, which has now been reversed as a result of increased management efforts between the bordering countries. However, little is known about previous human impacts on the lake ecosystem, and possible relations to changes in its catchment area. To address this issue, we are investigating ecosystem changes over the past 15,000 years in a sediment core retrieved from the Gnadensee basin, combining data obtained from sedimentary ancient DNA, palynology, and X-ray fluorescence (XRF) analysis. Vegetational zones were reconstructed congruently by both pollen and DNA metabarcoding. The timing of changes and the species composition in the different zones suggest that vegetation was initially determined by climate and postglacial colonization processes, while the human impact has become decisive in the past two millennia. Mammal DNA obtained from the sediments mirror the environmental conditions reconstructed from the vegetation. Ongoing work is targeting the aquatic communities and will allow us to develop a comprehensive understanding of changes in the lake since the end of the Last Glacial.

Tracing species lineages through time and space using multiplexing PCRs

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Sedimentary ancient DNA (*sed*aDNA) has proven to be a powerful tool for the recovery of species level data from a variety of ancient sediments. However, population level data can be more difficult to obtain due to either a lack of taxonomic resolution for the molecular method used or being dependent on a high amount of DNA template and extensive reference material. Here we present the potential of multiplexing different PCR markers together to retrieve population level genetic data from sedaDNA. *Vaccinium uliginosum* (Ericaceae) was chosen as a test species due to its present day intraspecific variation and distribution. It has a circumpolar distribution and can be found at higher elevations south of the Arctic. Within Europe, *V. uliginosum* has three known lineages and multiplex markers were developed to target these based on the chloroplast data generated by the PhyloAlps and PhyloNorway sequencing projects. The resulting 38 markers were tested on lake *sed*aDNA samples from five different sites located in northern Norway, the Alps and the Polar Urals, which contain the extent of present day *V. uliginosum* variation. All main *Vaccinium* lineages and markers could be recovered from the *sed*aDNA data, where for each sample on average 28.4 (+/-9.1) makers were present containing an average of 33 (+/-12.8) marker variants. All samples were dominated by a single population, except one alpine site which had co-occurrence of two different populations in the most recent sample. Multiplexing different markers is a promising tool for generating population level genetic information. The relatively low cost and sensitivity enables the processing of numerous samples, which will allow researchers to track populations through time and space.

A systematic evaluation of hominin and faunal DNA preservation in Pleistocene sediments

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In recent years, sediment DNA analysis has become an increasingly important tool for inferring the past presence of species even in the absence of macroscopically visible remains. The various taxa from which DNA has been isolated from sediment also include Neandertals, Denisovans and modern humans, demonstrating that it may be possible to reconstruct past human occupation at archaeological sites at much higher spatial and temporal resolution than previously imaginable. However, beyond a few proof-of-principle studies, systematic investigations are missing to determine the success rate at which hominin and faunal DNA can be recovered from archaeological sediments and to identify factors that may affect its long-term preservation.

Here we investigate the preservation of hominin and other mammalian DNA in more than 800 sediment samples collected at 148 archaeological sites in Europe, Asia and Africa with evidence of anthropogenic activity, including caves, rock shelters and open air sites. The archaeological layers sampled date mainly to the Middle and Late Pleistocene, but samples from Holocene layers were also included. To determine the taxonomic composition of mammalian DNA at high resolution and to allow the detection also of rare taxa such as hominins, DNA libraries were prepared from each sample and enriched for mitochondrial DNA by hybridization capture. In addition, an improved computational framework was developed to assign the resulting sequences to the biological families (and in some cases the species or populations) they originate from and to evaluate their ancient origin based on the presence of ancient DNA damage patterns.

Tests performed on simulated data indicate that our newly-developed analytical pipeline outperforms existing ones in terms of accuracy and speed. Preliminary data suggest that ancient DNA is, on average, best preserved in sediments from caves, followed by rock shelters and open air sites. Geographic and temporal limits of DNA preservation closely track those previously observed with the analyses of skeletal remains. We hope that the rich empirical data presented here will help to devise optimal sampling strategies in future studies, especially with regards to the number of samples that should be analyzed and the contexts that are most promising for sediment DNA analysis.

Circumarctic changes in herbivore populations over the past millennium

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Arctic ecosystems are currently undergoing severe changes due to climate change and direct anthropogenic interference. Numerous Arctic and Subarctic communities directly depend on the herding and hunting of large herbivores. The presence and abundance of large herbivores is a crucial factor and an indicator of ecosystem functioning and community composition. Thus understanding the relative impacts of climate, herbivory and human management on ecosystems, in particular on vegetation, is of paramount importance for their long-term sustainability and conservation, as well as for its inhabitants.

We examined the occurrence and abundances of large and small herbivores (e.g., reindeer *Rangifer tarandus* and Arctic lemming *Dicrostonyx torquatus*) over the past millennium on a circumarctic scale using ancient DNA isolated from sediment cores of twelve lakes situated in Canada, Iceland, Norway (mainland and the Svalbard archipelago), north-western Russia, and northern Siberia. The 137 analyzed samples covered an age range of over 1,000 years in each case. Hybridization capture was used to enrich mammal DNA, and in additional, plant metabarcoding data were used to assess differences in vegetation structure over time and between sites. Overall, sequencing read counts annotated to mammalian herbivores showed contrasting patterns between sites, however, few pronounced changes were observed over time, suggesting that the local signals reflected relatively consistent occurrence of these species over the past thousand years and more. However, a documented near-extirpation event of the Svalbard reindeer population in the early 20th century and its subsequent recovery were reflected in the time series of reindeer read counts from the respective sediment core. The vegetation data supported our conclusion that herbivory related to pastoralism has been an integral component shaping these Arctic ecosystems.

In remote regions with comparably scarce historic documentation of land use and pastoralism practice, well-informed ecosystem management and planning of resource use depend on alternative sources for understanding the history of long-term use. The continuity of herbivory and associated land use over the past millennium reflected by our results provide important decision support data for nature management and will inform scenario building to allow for better adjustments to future large-scale changes due to climate warming and anthropogenic pressure.

Comparison of environmental aDNA methods in late glacial and early holocene samples from Hässadala and Atteköpsmosse (southern Sweden)

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Environmental DNA extracted from ancient sediments has been increasingly used in paleoecological studies. These studies take advantage of recent improvements in molecular methods and bioinformatic processing of data, but it is unclear whether data can be reasonably compared across methodologies. A question that remains is whether different molecular methods or even similar methods in different laboratories produce consistent results from the same samples. Further, it is unclear which method performs better in terms of detectability and taxonomic resolution, how much overlap exists between them, and how molecular data obtained from new methods is related to traditional proxies such as pollen and macrofossils.

Here we compare published proxy data with three DNA methodologies executed across three independent labs: trnL P6-loop (flora) metabarcoding, shotgun sequencing, and targeted capture. We applied these methods to two well-studied lake sediment archives from southern Sweden, Atteköpsmosse and Hässeldala Port, covering the transition period from glaciation into the early Holocene (15.5 – 10 cal. kyr BP). This period exhibits strong climatic changes of contemporary ecological relevance. We investigate: the difference between single and double-stranded shotgun libraries; molecular data vs published proxy data; and metabarcoding vs capture targeting full vertebrate and invertebrate mitochondrial genomes together with plant barcoding genes (matK. rbcL, ITS1, and ITS2).

Preliminary results show that shotgun metagenomics describes a flora similar to metabarcoding when mapping ancient DNA reads against chloroplast and mitochondrial genomes, while substantially more reads were recovered when the same data is mapped to a nuclear DNA database. Both shotgun metagenomics and metabarcoding recover, in addition to plants, the microalgae Nannochloropsis. Overall, metabarcoding detected few plant taxa, with a large proportion of samples showing no reads, while shotgun metagenomics in combination with the nuclear database, recovered a more complex herbaceous flora with trees/shrubs such as Salix and Betula present already at 14.5 cal. kry BP.

The first look at the data shows that with nuclear databases, shotgun metagenomics might outperform metabarcoding to detect ancient flora, especially with degraded DNA, due to its ability to target shorter DNA fragments (30-45 nucleotides).

Holocene marine ecosystem dynamics off central West Greenland traced by ancient DNA

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The West Greenland shelf is a diverse and biologically unique arctic ecoregion harboring marine areas of international value like the North Water polynya and the Melville Bay Wildlife Sanctuary. Model projections suggest that the shelf will be increasingly affected by sea-ice loss and freshwater discharge from the Greenland Ice Sheet. Large uncertainties prevail on how the regional diversity and ecosystem structure will change in the future, partly because ecological responses are highly complex and because modern long-term observations cover timeframes already affected by climate change. This is raising questions on how to define baselines for evaluating observed changes, and on how to disentangle the effects of human impact and natural climate variability. As ocean sediments are natural archives of the past, they provide vital insights into the natural variability of ecosystems and long-term biotic responses to environmental change. Here, we present a Holocene sedimentary ancient DNA (sedaDNA) record to explore past marine ecosystem dynamics to climate variability off West Greenland over the past 8,500 years. We applied targeted amplicon sequencing of a diatom-specific (rbcL) and a universal eukaryotic (18S V7 region) marker to a well-dated marine sediment core retrieved on the shelf off the Upernavik Ice Stream (AMD14-204C; Lat. 73.261, Long. -57.899, 987 m water depth). Our record revealed a high taxonomic diversity, including many taxa whose body parts are usually not preserved in sediments, such as copepods, polychaetes or jellyfish. Sequence variants representing 251 families in 31 phyla were retrieved for 18S and 19 diatom genera in 14 families for the rbcL marker, respectively. Taxonomic assignments of diatom-derived sequences contain typical cold-water (*Porosira glacialis*, *Chaetoceros socialis*, *Thalassiosira gravida*) and sea-ice associated species (*Nitzschia frigida*), including species indicative of sea ice and brackish water conditions (*Cylindrotheca closterium*, *Pauliella taeniata*). Many sequences remain unassigned, indicating the need for a close collaboration between taxonomists and geneticists to fill this gap for unlocking the full potential of sedaDNA in the future. We will discuss the exceptional potential of ancient DNA to improve predictions of marine productivity and biodiversity, and to support ocean and cryosphere risk assessment and conservation efforts.

Inferences into subsistence strategies at Kirkhellaren Cave, Norway using ancient human and faunal DNA from sediments

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Kirkhellaren Cave hosts one of the most spectacular and best preserved archives of integrated cultural and ecological change during the Holocene in Northern Europe. Located 50 km off the Arctic Norwegian coast on the island of Sanna, this site boasts a uniquely rich faunal assemblage of marine species that are frequently underrepresented in deep-time records and terrestrial settings. Recent excavations showcase continuous human presence since 10,000 cal BP, with the identified communities predominantly associated with hunter-gathering and fishing practices. The site has functioned as a significant focal point for communal gatherings throughout time, with evidence of strong network interaction for both Northern Fennoscandic and Southern Scandinavian populations. The cave thus constitutes a rare opportunity to reconstruct long-term marine ecological changes in tandem with human impact. In spite of the cave's detailed archaeological context, no ancient genomics-based approach has yet been attempted to characterize its human and faunal profile, or how these profiles changed over time. One particularly promising method is the prospect of retrieving ancient DNA from sediment samples, which has been previously demonstrated to work successfully in long-occupied cave sites. Here, we report recovery of both ancient human and faunal DNA from several sediment samples, representing a range of layer depths and time periods at Kirkhellaren (approx. 1800-3400 BP with aDNA; samples up to 10000 BP were analyzed). We identify DNA from diverse ancient faunal taxa (*Phocidae*, *Canidae*, *Bovidae*, *Mustelidae*, and *Balaenopteridae*). These findings are generally consistent with the archaeological record and historical interpretation of the site's function; however, we also find the first direct evidence for taxa such as *Canidae*. We also present preliminary population genetics analyses of the identified ancient human DNA, and place it in the broader context of ancient Europe. By retrieving DNA directly from occupational contexts, this study provides the first genetic-based insight into the lives of the ancient Norwegian populations who lived in the region surrounding Kirkhelleran Cave. It also demonstrates the important role that ancient sediment DNA can play in future studies of human prehistory, by enabling genetic material to be analyzed even in the absence of faunal or human remains.

The Dog in my Data: Impact and quantification of faunal aDNA that maps to the human genome

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The ability to obtain ancient DNA from sediments has dramatically increased the times and archaeological sites available for genetic study. Recent advances have enabled the retrieval and analysis of genome-wide human nuclear DNA, allowing sediment samples to be included in population genetic analyses, and offering population-level insights rather than simply determining the presence and/or absence of taxa or species. One important aspect of sediment DNA is its metagenomic character; a single sediment sample typically contains DNA from multiple species. Although this allows researchers to study many species, even ecosystems, rather than single individuals, it also complicates analyses. In particular, faunal DNA may be challenging to distinguish from human DNA.

This issue is not new to the field of aDNA: the bones and teeth that are typically used in human aDNA studies also contain abundant bacterial DNA. Due to the large evolutionary divergence between humans and bacteria, this non-human DNA is generally removed by a) mapping the DNA to the human genome, and b) restricting to longer DNA fragments.

Here we investigate the extent to which faunal DNA may “mis-map” to the human genome, and the effects this DNA may have on typical population genetics analyses. In short: We find that small amounts of faunal DNA do map to the human genome, and that this DNA can have an outsized effect on analyses. The regions to which this faunal DNA maps are different between different species, frustrating simple solutions such as removing conserved sequences. However, in all tested species, this DNA maps to regions of the genome that are used for typical population genetics analyses. We additionally find that even small amounts of faunal DNA (~2-5% of mapped reads) can dramatically alter basic population statistics such as the f3 statistic, a measure of shared genetic drift between two samples. Finally, we present a simple method for quantifying this mis-mapping DNA that is agnostic to the faunal species, and discuss best practices for identifying samples where faunal mis-mapping is an issue. This method is easily extensible to non-human analyses, making this of general use to the fields of environmental or sediment DNA.

Molecular island archaeology: sedaDNA data from small islands in the Celtic fringe

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Islands on the Celtic fringe of Europe can be seen as test-cases for investigating the resilience and sustainability of small communities in the face of both climatic and economic change. Were they fragile socio-ecological systems precariously surviving due to economic 'windfalls' or resilient hybrid systems that could respond to changing socio-economic conditions and environmental events? Population levels on these islands generally grew from the medieval periods, when the islands were politically and economically important and sustainable until the 18th centuries after which all suffered depopulation to different extents, and at different rates. Here we use newly developed molecular methods (particularly sedaDNA and lipid biomarkers) to investigate the changing landscapes and life-scapes of four islands, three in the Southern Hebrides and one off the Northern Irish Coast. These islands all share access to marine resources and have strong cultural connections, but our studies reveal divergent histories especially in the post-medieval period. The detection of faecal steroid biomarkers varies between sites, but temporal differences in the initiation and persistence of human occupancy between islands are identified using stanol ratios. Whilst our application of lacustrine faecal steroid analyses successfully extends understandings of the timings of (post)Medieval population and land use change on these islands, it also highlights key areas of uncertainty associated with steroid taphonomy that must be explored before this approach can be used to obtain quantitative population reconstructions. The ability of sedaDNA metabarcoding to reveal cultivars invisible to pollen analyses, such as potato and cereals to species level, makes the technique able to chart the most important socio-environmental events that effected these communities such as the potato famine of the mid 19th century. The data reveals that these islands had periods of convergent and divergent histories and also lends itself to the modelling of combined population-grazing-crop-erosion modelling of catchments on these islands.

Session 92: Zooming into the Quaternary Research in South Asia: Understanding the landscape-cultural-climatic evolution

Terraces, Tools and Time: A Review of Quaternary Environmental Studies in South Asian Prehistory

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I discuss changes in conceptual approaches in the study of Quaternary environments in South Asian prehistory. Variability in theoretical and methodological approaches adopted by Western and South Asian scholars, along with fluctuating dynamics in the academic interaction between archaeologists and other palaeoscientists, has influenced the interpretation of site contexts and past behaviours. The holistic approaches of the 19th c. were strongly marked by Robert Bruce Foote, whose work drew upon strong geological and ethnographic elements, but contrasted with starker studies during the 1930s, which focused rather on broad correlations between river terraces and cultural sequences. Post-independence developments, such as the decision to incorporate Quaternary environmental sciences into archaeology departments, increasing specialisation, interdisciplinary collaborations, and revolutions in chronometric dating all transformed archaeological studies. Approaches, however, varied greatly depending on the conceptual strategies adopted from the perspectives of archaeologists or other Quaternary scientists, leading to multiple ways of interpreting site contexts, stratigraphy, taphonomy and hominin behaviour. These issues are closely tied to the continuing epistemological reshuffles in the archaeological and Quaternary sciences, with implications for academic curricula, degrees and the categorisation of specialists on the South Asian educational scene. Awareness of these undercurrents is particularly important for appreciating ways in which studies in archaeological sciences are funded in India and by international agencies. In recent years, specialised studies in various fields have driven new dynamics between archaeologists and "palaeo" scientists – each, however, displaying varying degrees of overall understanding of the nature of the archaeological record. On the positive side, this has led to an increase in interdisciplinary collaboration. On the negative side, the application of specific methods without archaeological research questions and the proliferation of publications on archaeological issues that lack "palaeo" specialists is an issue that demands greater attention. I conclude with issues relating to public outreach in the context of studies linking palaeoenvironments to archaeological sites – an aspect of crucial importance when considering the rapid destruction of sites and Quaternary deposits in one of the most densely populated and rapidly urbanising countries on Earth.

Optically stimulated luminescence (OSL) chronometry and environmental context for human occupation during LGM in the Lower Ganga Plains, Eastern India

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Lower Ganga Plain (LGP) is covered by fluvio-deltaic deposits formed by the tributaries of Ganga, Brahmaputra, and the rivers of the Chottonagpur plateau. After draining through the Upper Ganga alluvial plains, in the LGP region, several discrete sites of microlithic technology are reported, but information on technological and chronological approaches are restricted from this region. Microliths tools are frequently thought to have been associated with modern human technology along with a combination of tools, including projectile weapons and other effective hunting techniques. Mostly, these small blade lithic toolkits were thought to be used in India, Europe, and Africa to hunt medium- and large-sized grassland and forest creatures, or as adaptations to shifts in environmental conditions during significant climatic change.

The LGP region is well known to have several evidence of modern human occupation, especially through microlithic assemblages. However, the missing vertebrate fossils associated with the stratified horizons and their connections to the environments are yet to be recognized. We report here, for the first time, *in situ* fossils (bones and teeth) of *Bos namadicus* and *Boselaphu stragocamelus* associated with microliths toolkit from a stratified Late Quaternary alluvium sequence at the Barakar region, Eastern India, which indicates human occupation of LGP was most likely constrained between 17 and 18 ka. The paleoclimatic information for this time period has been constrained through stable isotope and mineral magnetic studies. The $\delta^{18}O_{SC}$ value (rainfall proxy) indicates isotopic depletion -6.1‰ during the ~18 to 17 ka period, implying intensification of the Indian summer monsoon (ISM). The co-existence of higher $\delta^{18}O_{SC}$ (-1.4‰) and $\delta^{13}C_{SC}$ values (-2.4‰) suggest that the C_4 plants (grassland) dominated during the ~14.2 ka event, suggesting an impact of the dry climate of the *Bølling period.* Environmental magnetic proxies clearly indicate a shift from the mixed anti-ferromagnetic mineral of the Last Glacial Maximum (LGM) to detrital ferrimagnets post-LGM. These findings contribute to our understanding of human activity in stronger ISM seasonality and have implications for understanding cultural connections and local migration across Eastern India during the LGM period.

Fire history of the western Himalaya and its linkage to climate and human: inferences from the sedimentary black carbon

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Understanding climate-human-vegetation-fire interaction in the past plays an important role in deciphering modern fire dynamics associated with climate change and anthropogenic perturbation. Fire has played a significant role in the human evolution and its diversification across the continents and hence studying past fire events provides an insight into civilizational imprints in the past. To contribute towards the understanding of the fire history and its linkages to climate change and human evolution in the Himalayas, black carbon (BC)concentrations and its carbon isotope have been analysed in the two sediment cores,extracted from a paleo (Forest Block : FB) and live lake (Wular Lake : WL) in the Kashmir region of India. The chronology of sediment cores has been established using the radiocarbon dating, which covered the last 33 Cal ka BP (FB) and last 4 Cal ka BP (WL) of the Quaternary period. The variation in BC concentrations in the FB sediments showed fireintensity to be many fold higher during the Holocene (after 10 Cal ka BP), possibly due to increased human population and related activities in the region. The BC concentrations in WL sediment showed that the fire history of the last 4 Cal ka BP in the region wasdominantly controlled by the human activities such as agriculture settlement, pastoralism, and smelting of metals. The carbon stable isotopes data of FB and WL sediment cores haveshown change in humidity in the region and its linkage to the strength of westerlies.

The Physical Anthropology of Sri Lankan Vadda People: An Evaluation of Research History

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The Vaddas (indigenous forest dwellers) of Sri Lanka have lived in various ecozones and have been linked to the Mesolithic population, dating to ca. 48,000 BP. The tropical rainforest belt of the island, which is home to the last groups of hunter-gatherers, has been their preferred habitat. These 'pristine' habitats have played a key role in their subsistence strategies and behavioral patterns. *Homo sapiens balangodensis*, or Mesolithic man, is considered to be the direct biological and cultural ancestors of Vaddas, since the first physical anthropology and ethnography of Vaddas were undertaken by Sarasins (1892, 1893, and 1908). These studies influenced later researchers (Seligmaan and Seligmaan, 1907 and 1908) to investigate the Vaddas and connect them to the island's Stone Age cultures. Deraniyagala (1953), for example, linked Sarasin's analysis of Vaddas to physical characteristics found in Mesolithic skeletons such as dolichocephalic, thick brow ridged, and the well-worn third molar male. Lukacs and Kennedy (1981) revealed that the protohistoric teeth found in the dry zone are almost identical to Vadda's, which for him explains the similarities in part with cultural practices and certain ecological shifts over time. Many of these studies claim cultural and biological continuity from the Mesolithic population through Vaddas to the modern population of Sri Lanka. On the contrary, the statistical approach adopted by Roberts *et al.* (2018) revealed that the Vadda population significantly differs from Mesolithic foragers, while Ranaweera (2014) confirmed their genetic closeness to the Indian Subcontinent. Thus, the debates continue.

Previous studies, however, paid less attention to the physical anthropology and osteology of Vaddas in a broader historical and evolutionary perspective. No attempts have been made to understand biological evolution and variations and to emphasize the importance of evolutionary history and human genomes that are strongly influenced by the environment. This paper attempts to identify lacunae in previous research and look beyond drivers of change in knowledge to underpin larger historical, ecological, and cultural processes underlying their present and future.

Keywords: Vadda, Indigenous forest dwellers of Sri Lanka, Anthropometry, Ethnography, Physical Anthropology

Late Quaternary Alluvial History and Geomorphological Mapping of Purna River Basin, Maharashtra, India.

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The Purna River (PR) originates in the Ajanta Range of hills and is an important left-bank tributary of the Tapti River. Numerous multidisciplinary field and lab studies concentrating on fossil and archaeological localities from the Tapi river valleys of Maharashtra are generating significant findings, enabling researchers to address important evolutionary questions that have long confounded the field, i.e., did technological advancements and symbolism facilitate the dispersal of modern humans in terms of behaviour? What role did major climatic fluctuations and environmental events (e.g., YTT super-eruption) play in the dispersal of modern humans across Asia?

Questions such as these are paramount in understanding alluvial sequence during the Late Quaternary, local geomorphology, and hominin evolution, extensive fieldwork has been carried out along the PR Basin. Based on their lithological, physical, and field properties, provably 74 ka YTT was preserved at two to three different localities in the Late Quaternary Purna sediments, which have been classified as primary and secondary in nature. These ashes are light grey, massive to softly laminated, and they form discontinuous beds that are 10-20 cm thick and extend laterally for >100 m. Pre-tephra successions at both sites preserve a variety of biogenic and non-biogenic structures that are formed in response to specific environmental conditions, such as pedogenic calcretes, and rhizolith balls. Tephra-bearing successions are classified as belonging to four lithofacies: paleosol; planar cross-stratified gravel; matrix-supported massive gravel, and silty clay. In the Kaplieshwar Quaternary formation, previously dated from 70 ka to >100 ka, Gandhigram previously dated >700-800 ka, correlates with the late to middle Pleistocene. Also, the high-resolution satellite data were used to better understand the landforms and their process and drainage pattern demarcation for basin area planning and management.

Long-term (~11,000 cal. years BP) environmental dynamics and apparent carbon accumulation rates (LORCA) in Sebangau peatland, Central Kalimantan.

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Tropical peatland covers 89 Gt C of the total carbon (C) pool of which 65% are in Indonesia. These peatlands have evolved due to changes in climate and anthropogenic factors. To assess the future of peatlands, establishing the mechanisms of long-term apparent carbon accumulation rates (LORCA) of peat to changes in the peatland ecosystem is needed. Using palaeoecological and geochemical proxies, this study reconstructed the past peatland ecosystem (zones) of vegetation composition, hydrological conditions and peatland disturbances, and evaluated its relation to LORCA and carbon density for the past 11,000 years BP in Sebangau National Park (SNP), Central Kalimantan. The results suggest that the mechanisms of LORCA in each zone depend primarily on vegetation composition which contributed to the amount of recalcitrant organic matter in peat and the frequency of flooding events that influenced the vegetation growth and peat decomposition. The highest LORCA (16.4 g C $m^{-2}yr^{-1}$) and carbon density (332 Mg ha^{-1}) were recorded for ~2300 to 300 cal. yr BP (Zone B) during wet conditions, minimal flooding and with primarily PSF and LMS species (i.e. *Eurya*, *Ilex*, Melastoma, Euphorbiaceae, *Campnosperma* and Myrtaceae). In contrast, the lowest LORCA (7.9 g C $m^{-2}yr^{-1}$) and carbon density (172 Mg ha^{-1}) occurred between ~4500 to 2000 cal. yr BP (Zone C) due to dry conditions with high fire severity events and the transition from PSF to OV species. These conditions were similar to the young peat layer in Zone A (~350 cal. yr BP to present), which points to possible high aerobic peat decomposition and lower LORCA in the long term. Compared with other Indonesian peatlands, this study showed that the LORCA in SNP had similar trends over the past 11,000 cal. yrs BP with the other peatlands sites but was on the lower range in each zone despite having similar vegetation composition. The main reason for different LORCA in these peatlands could be due to flooding tendencies based on its location to the rivers or coastline and the possibility of varying rainfall patterns in Sumatra and Kalimantan.

Evolution of Landscape in the Foothills of Assam- Bhutan Himalayas: An Insight into Climate- Tectonic Relationship

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Himalaya is formed due to continent-continent collision between the Eurasian and Indian plates. This established a southward propagating fold and thrust belt (FTB) system with major boundary thrusts viz., Main Central Thrust (MCT), Main Boundary Thrust (MBT) and the Main Frontal Thrust (MFT). The MFT is the southernmost fault that separates FTB from the foreland basin, which is a flat alluvial land filled by sediments from the erosion of exhumed FTB. The Landscape at the foreland of the active mountain fronts such as the Himalayas results from the climate and/or tectonic interactions. These are result of crustal movement and erosion or deposition by surface processes. They are important geomorphic archives that preserve information about such changes/activities in the past. Thus, the landscape in the foothills preserves the signature of deformation events and, at the same time, also records changes in the monsoonal rainfall, controlled by glacial and interglacial events. The present study attempts to understand the evolution of alluvial fan deposits in the Assam- Bhutan Himalayan foothills of the Kokrajhar District of North-East India. The study mainly focuses on the uplifted 30 km long fluvial deposition from the Pinkhua Khola River in the west and Leu Pani in the east. The study is critical because it will help understand the southward propagation of the Himalayan fold and thrust belt. The initiation of the faulting events is marked by the clay layers, which were dated using OSL; the dating of clay layers from the hanging wall of three blocks suggests that the FTB was activated ~76 ka and experienced three other phases of deformation at ~45 ka, ~27 ka and 12 ka. These hanging walls also record the monsoon intensification during the MIS3 and MIS1.

Inequality and urbanisation in the landscape dynamics of the Indus civilisation

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As the centennial anniversary of the rediscovery of the Indus civilization approaches in 2024, archaeology has assumed an increasingly important role as a Quaternary science. At this key moment, a growing number of archaeologists are returning to one of the discipline's pressing challenges: the investigation of how inequality has materialized within human landscapes. The Indus civilization provides a key dataset for this investigation. One of the world's first urban societies, the Indus emerged around 2600 BC in South Asia, a pivotal transformation that prompted a dramatic re-organisation of social ecologies. Many scholars have adopted the assumption that the defining feature of urbanization was the dense spatial concentration of consumers, often headed by a politically and economically stratified ruling class. However, archaeological evidence from nearly a century of research at Indus cities challenges this view. It has long been clear that there is no evidence of palaces, elaborate tombs, or individual aggrandizing iconography in Indus cities, and many political and economic benefits were widely available, suggesting a conspicuous absence of stratification among urban communities. However, over the last two decades, our understanding of Indus landscapes has expanded beyond the cities, where archaeologists have traditionally focused their research. Landscape archaeologists in South Asia have documented a substantial and growing number of small-scale settlements, revealing that the Indus was far more extensive that many of its urban contemporaries, connecting diverse communities located far from one another in environments that were as different from one another as the mountainous Himalaya and the arid coasts of Gujarat. In this talk, I will review recent developments in archaeological approaches to inequality at the landscape scale, and discuss how emerging evidence from Indus landscapes can help us rethink one of the most important social ecological transformations known to Quaternary science.

Computational approaches to map Cultural Heritage at risk by recent anthropic activities: examples from South Asian drylands

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The remote assessment and analysis of disturbances and damage affecting the preservation of Cultural Heritage (CH) have become particularly important over the past decade, and has benefitted from improvements in the availability of global geospatial data and innovations in software and satellite to UAV image processing techniques. Moreover, the consolidation of cloud-based data analysis and visualisation platforms, such as Google Earth Engine, offers a game-changing scenario in CH documentation and (geo)archaeological landscape investigations, particularly in remote areas with little or almost no ground information.

In this paper, we will present ongoing satellite-based developments and ready-to-share algorithms aiming at the rapid mapping and monitoring of activities of anthropic origin, such as agricultural development and urban growth, as well as geohazards that pose an urgent threat to site preservation. We will focus on applying AgriExp, a new algorithm and method workflow that uses free and open-source Sentinel-2 satellite imagery to automatically map sites at risk of encroachment by recent agricultural expansion. The algorithm is tested in the fragile archaeological landscape of the Cholistan Desert in eastern Pakistan. The area was central to the development of the Indus Civilisation (c. 3500-1600 BC), and is home to hundreds of well-preserved archaeological mounds. As with many other drylands elsewhere, recent developments in irrigation schemes are threatening the preservation and visibility of many archaeological locations, and often, such new developments are undetected. We will discuss the case study of Cholistan in the context of new appraisals for data sharing and method reproducibility. The availability of the code ensures that this and other similar methods can be rapidly integrated for large-scale new heritage policies on site conservation in similar South Asian drylands and elsewhere.

Reframing the "Proto-indica debate" through a niche-construction framework: the impact of landscapes, plant ecologies, and human lifeways on early rice domestication.

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The mosaic nature of the South Asian subcontinent, with its diverse environmental, ecological, riverine and climatic zones, make it one of the richest settings for studying changing human lifeways across the Quaternary Period. Change occurred at numerous scales, and the complex interaction between people and their environments is one of the ever-standing challenges facing archaeologists. One debate that remains constant within this is the nature of early agriculture and the shift between hunter-gatherer-fisher-forager lifeways and farming lifeways which developed in numerous forms at numerous times within South Asia, as might be expected of this diverse landscape. The debates are however perhaps most heated in the Ganges Plains, where the nature of early rice use continues as a topic of discussion. Questions remain over whether rice was domesticated in India before, during or after the arrival of Chinese domesticated *Oryza japonica*, what the status of rice in India was (gathered, cultivated or grown) before the arrival of *japonica*, and whether human interactions with *Oryza nivara* (wild rice) led not only to changes in rice, but also to changes in lifeways and the ecologies and environments around sites in the plains. While a lot of debate has been had on the nature of the rice itself, this paper will instead explore the implications of the various rice domestication hypotheses from a broad environmental and ecological stance, asking what impact a local domestication or incoming hybridization model might have had on the changing habitats and niches both plants and humans would have inhabited. Through this niche-construction theory, and incorporating new data from the Sakas excavations, this paper asks what impact might different interactions with rice have had on lives and landscapes, and how might this altered perspective allow us to move the debates around the Mesolithic-Neolithic transition forwards?

Herd management culture and climate: A historical overview from the perspective of biogenic carbon and oxygen isotopes

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The early Holocene witnessed the beginning of animal domestication in northwestern South Asia. By the mid-Holocene, this practice had spread throughout South Asia into different climatic zones and was incorporated into different cultures. Currently, over 6% of India's population actively engages in specialized pastoralism. However, despite its long history of existence and importance in today's Indian economy, our understanding of how climate and culture influenced the way domesticated animals were raised in this part of the world is extremely limited. This is primarily due to the lack of systematic biogenic isotopic analysis of domesticated animal remains from archaeological settlements.

Recently a few studies were carried out to reconstruct human-animal interaction in South Asia, but unfortunately, they were primarily confined to the Indus region. This has extensively confined our understanding of animal herding practices exclusively within the Indus region. This presentation will showcase the preliminary results of a pan-Indian biogenic isotope project. This is one of the most significant ongoing projects in India that analyses biogenic carbon, oxygen and strontium isotopes from archaeological animal remains. In this presentation, we will discuss the results obtained from cattle and buffalo, the primary domesticates in the Indian subcontinent, in order to understand how rainfall, availability of wild vegetation and agricultural fodder influenced, and historical knowledge and cultural practices determined the way these animals were managed. Along with the cultivation of grains and the production of specialized crafts, different forms of pastoralism also played a significant role in shaping ancient economic and political practices of historical and pre-historical south Asia. Reconstruction of herding practices, therefore, is a crucial step to understanding how ancient Indians perceived and utilized their surrounding environment and herds, and how cultural practices and the interaction between pastorals, cultivators, craft producers and the people in power historically inflicted such perception and utilization of the natural and cultural environment.

Riverine legacies and the archaeology of Jammu in North-western India: a geoarchaeological and remote sensing approach

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This paper will present the ongoing work of RIVERINE, a research project that aims to investigate the long-term land use and settlement dynamics that shaped the outer plains of Jammu in north-western India. The fluvial complexities in the region are volatile, owing to the erratic and ferocious rivers of the Indus system and its tributaries that drain its vast area. Although these rivers are generally destructive, they are also a major source of fertile alluvium, which contributes to the dense population concentration in these areas. The combination of urban expansion, mechanized agriculture and continuous river shifting and aggravation poses severe threats to the preservation of dozens of archaeological mounds that attest for a long-span occupation ranging from the Early Historic period to medieval times, with the earliest occupation dating back to the Neolithic and Chalcolithic periods. The project integrates 1) archaeological legacy data, in the form of published and unpublished archaeological literature, 2) legacy spatial data, such as historical topographical maps and declassified satellite imagery, coupled with 3) remote sensing observations, to accurately detect the location of ancient mounds and to map and monitoring short to long-term land cover trends, including landscape dynamics such as seasonal flooding, river migration and associated paleochannels. We will discuss our remote-based efforts with the preliminary results of new geoarchaeological and ground-truth surveys, aiming at providing a better understanding of the spatial and chronological relationships of ancient settlements and rivers in the region and in the broad riverine landscapes of South Asia.

Carved by Rivers: Landscape and Environment in Copperplate Land Grant Charters from Deltaic Bengal (c. 600CE–1200CE)

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How can we rethink a landscape that belies cartographic fixity? How does an untameable environment record itself in the historical narrative? This paper looks at epigraphic records preserved in the form of copperplate land grant charters issued over a period of approximately 600 years to understand the shifting fluvial landscape that is the mouth of the Ganga-Brahmaputra-Meghna delta. The riverine topography that marks the southern portion of deltaic Bengal has created an amorphous space in and around the Sundarbans, the largest mangrove forest in the world. While this space has been studied for its unique bioclimate and exotic wilderness what remains largely untapped and disconnected from the scholarship are the remains of its rich material past. This paper is a methodological intervention in looking at epigraphic and archaeological material to understand the very landscape that produced them. An analysis of over twenty copperplatesthat record in minute detail the process of land transfers by the ruling dynasties of southern Bengal portray the region surrounding the Sundarbans as a fluid space, but nevertheless one that was constantly inhabited. It shows that this terrain, which has been and continues to be at the mercy of flood waters and the whims of its rivers, has in fact been constantly reproduced in historical time through human intention and action. Placing water at the heart of this narrative, this paper documents how the landscape inscribed itself on the memory and materiality of its human occupants.

Session 95: Impacts of abrupt climate change on ecosystems, landscapes and societies through INTegration of Ice-core, MArine and TErrestrial records (INTIMATE)

Speleothems as potential chronomarkers of volcanic eruptions and a novel tephrochronologic tool

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Speleothem records have shown great utility for reconstructing paleoclimate and paleoenvironment age-models based on radioisotopes combined with a series of proxies. However, the use of these records as precise and independent markers of volcanic eruptions is in its infancy. Previous speleothem studies have linked short and long-term changes in climatic proxies to volcanic eruptions while a handful of other studies report direct detection of volcanic aerosols in speleothems and potentially the detection of volcanic tephra. A recent study in Patagonia reported individual tephra shards from found, and analysed in situ within a speleothem. Using trace elements from a speleothem (SA1) from Southern Italy we found a peak in Mg, Sr and Ba/Ca around 15.2 ± 0.1 ka, based on U-Th method, which is statistically synchronous to the age of 14.9 ± 0.4 ka, based on $^{40}Ar/^{39}Ar$ dating of sanidine crystals from the caldera-forming event of Neapolitan Yellow Tuff (NYT), in Southern Italy. This highlights the potential of using speleothems as new contributors to the goals of INTIMATE (INTegration of Ice-cores, MArine, and TErrestrial records) for the last Glacial-Interglacial period. Future aims will be focused on acquiring higher-resolution trace element analysis, further constraining the age-model with additional U-Th ages and testing the potential of finding cryptotephra, which are tephra invisible to the naked eye. Direct detection of volcanic eruptions via tephra chemistry provides independent age markers and extends the tephra lattice into the speleothem record. It will facilitate high resolution correlation of volcanic isochrons in speleothems with those in other climatic records. In addition, preservation of both the volcanic signature and its climatic effect within a single record will permit detailed investigation of the of the lag time and duration of volcanic climate forcing.

A persistent and intimately close relationship between volcanism and climate throughout the Holocene

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Volcanic eruptions play a dominant role in driving climate, in ways beyond the established short-term influence on surface air temperatures. The observational record of the timing of volcanic eruptions, their locations, magnitudes of sulfate aerosol injection is incomplete which limits our understanding of the sensitivity of the Earth system to volcanism and the vulnerability of social and economic systems to the climate impact of past and future eruptions.

Here we use an array of synchronized, accurately dated, high-resolution ice-core aerosol records from Greenland and Antarctica to reconstruct the timing, sulfur injections and source locations of 850 volcanic eruptions occurring during the Holocene (i.e., the past 11,500 years). Employing geochemical analyses on recovered volcanic fallout products (i.e. crypto-tephra, heavy metals, halogens, sulfur isotopes) we trace numerous ice-core eruption signals to known volcanic eruptions (including major lava floods from Iceland and caldera-forming eruptions in North America and East Asia).

Using transient climate model simulations including the new volcanic forcing and ultra-long tree-ring chronologies sensitive to volcanic perturbations we can then pinpoint the exact dates of Earth's largest volcanic eruptions since the last ice age, allowing us to analyze the responses of ecosystems, landscapes and human societies following such rare volcanic extreme events.

The persistent and intimately close relationship between volcanism and climate that we identified throughout the Holocene provides strong constraints for the precise timing of rapid climatic events (such as the 8.2 ka event, recently introduced by the International Commission on Stratigraphy as a formal Global Boundary Stratotype Point between the Early- and Mid- Holocene). Going forward, this will allow the paleoclimate community to reconstruct inter-annual to multi-decadal climate variability from a wide range of climate archives that cannot currently be resolved by existing proxy compilations.

A new Lateglacial to early Holocene pollen record from Lake Suigetsu, Japan: Contrast with the N. Atlantic region and implications for human history

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Pollen analysis and pollen-based climate reconstruction of the Lateglacial to early Holocene (ca. 16.7 to 10.2 IntCal20 kyr BP) part of the “SG06” core from Lake Suigetsu, Japan has been completed at 1 cm (*ca.* 13 yrs) resolution, yielding a total of 510 pollen spectra. Using the exceptionally precise chronology of the core which is basically coherent with Hulu Cave’s U/Th chronology (Bronk Ramsey et al., 2020), as well as the transfer function between Greenland and U/Th age scales established by Adolphi et al. (2018), the climate reconstruction from Lake Suigetsu has been compared with Hulu, NGRIP, and some other key archives from across the world at multi-decadal precision. The result indicates that the Holocene-like warm and stable mode of the climate in the Far East started as early as 15.0 IntCal20 kyr BP, with added (though much attenuated) influences from the North Atlantic processes such as Lateglacial interstadial (equivalent to the Bølling and Allerød) and subsequent cold reversal (equivalent to the Younger Dryas). Climate became particularly unstable when the N. Atlantic was in the Glacial mode whilst the Far East was already in the Holocene mode, or *vice versa*. Periods of the earliest domestication of plants, origin of agriculture, and the earliest construction of permanent settlements in the Middle East did not show simple correlation with warm or cold periods, but coincided with periods of climate stability. Stability of the climate typical of the Holocene made it meaningful for humans to plan for the future, and may have triggered a fundamental change in human lifestyles. Full details of the results are reported in Nakagawa et al. (2021) Global and Planetary Change.

Quasi-persistent rhythm in the climate and human activity recorded in a varved sediment from Mayan lowland

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We discovered varved sediments from a lake within Maya site of San Claudio, southeastern Mexico. This particular setting of the lake strongly implies that the sediment records the detailed history of both natural and human-induced environmental change. We recovered a 6.5 m-long perfectly overlapping sediment cores spanning over the last 5000 years. We performed stable nitrogen isotope ($d^{15}N$) analysis and ultra-high resolution (40 µm stepping; ca. 3 weeks) X-ray fluorescence (XRF) analysis. The $d^{15}N$ data indicate five periods of human occupation, which appear to be followed by abandonment and catchment instability. On the other hand, the XRF data indicated that the climate of this area (most likely evaporation-precipitation balance) exerted persistent cyclicity through the record, though the cyclic signal becomes less distinct and slightly noisier during the period of the Maya civilisation. Many of the detected peaks of the climatic cycles showed agreements with $\Delta^{14}C$ signals of tree rings. The typical interval of the peaks is centered around ca. 200 years. Based on these observations, we may tentatively conclude that the marked oscillation between dry and wet climates in this area was primarily driven by the Suess/de Vries cycle (ca. 200 years) of the solar activity.

The five episodes of human settlement uniformly have their counterparts in the peaks of the 200-year solar cycles, but do not correspond to all of them (albeit, the comparison template of the climatic signal itself becomes less clear – possibly because of the masking effect by human factor). This suggests that the Maya civilisation had certain resilience to the dry-wet oscillations, but climate could nonetheless contribute to significant decline of the civilisation when the resilience had already been undermined by other non-climatic factors, the candidates of which may include epidemy, political instability or unsustainable use of resources.

Atmospheric blocking as a stabiliser during abrupt climate change in eastern Europe during the Last Deglaciation

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Abrupt climate change has occurred frequently in Earth history, most notably during the termination of major glaciations in the Quaternary. Changes occurred over decadal timescales and destabilised or transformed landscapes and ecosystems. We use the Younger Dryas as a natural experiment to better understand the regional propagation of abrupt change. We applied hydrogen isotope analyses (δD) of plant wax lipid biomarkers as indicators of hydrological change and moisture origin from five lake records across Central Europe, namely lakes Meerfelder Maar, Steisslingen, Hämelsee, and Rehwiese palaeolake in Germany, and Lake Czechowskie (Trzechowskie palaeolake) in Poland. Using recurrence analysis, a method to detect and classify time-series and characterise dynamical regime shifts (tipping points), we identify the transition from warm to cold states, or from the relatively warm Allerød to the cold Younger Dryas, and return to the Holocene warm state. Further, isotopic gradients from the Allerød, Younger Dryas and early Holocene are compared with modern gradients, revealing spatial differences in the timing of the onset of the Younger Dryas event, in the magnitude and variability of change as well as the structure of the Younger Dryas event. We show that the pattern of δD responses during the YD were not consistent geographically, and that variation at different locations suggests greater climatic stability and smaller degree of change in the east. These spatiotemporal patterns are compared with modelling results and infer that atmospheric blocking over the Fennoscandian Ice Sheet (FIS) was likely the main driver of spatiotemporal patterns, creating a sustained high-pressure system over Fennoscandia deflecting the flow of westerly winds. This blocking effect only happens during summer as there are strong westerlies from September to April or May. Despite the abrupt climate change at the end of the Deglaciation, this resulted in a more stable climate during the YD event in eastern Europe, while western Europe was affected by major climate fluctuations during the second half of the YD because of weaker summer atmospheric blocking at the end of the YD meant more Atlantic inflow reaching MFM in the west but not in the east.

High continentality as a key driver of rapid deglaciation in Europe

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The deglaciation process of the Last Termination (17 to 9 ka BP) was largely (~50%) driven by a transient increase in orbital summer insolation over high northern latitudes with additional warming (30%) through greenhouse gases and interacting feedbacks (20%). Excess meltwater fluxes from vanishing ice sheets into the North Atlantic Ocean caused a series of abrupt cooling events (stadials). Simulations of the ~3000-years long Heinrich Stadial 1 (HS1, GS2) and ~1200-years long Younger Dryas (YD, GS1) require a massive, continued influx of freshwater to sustain stadial cooling giving rise to a “meltwater paradox”: most freshwater needs to be produced during the coldest periods. Recent proxy studies show evidence for stronger melting during stadial cooling from the European Ice Sheet (EIS). However, severe cooling registered in ice core and marine proxies requires an atmospheric driver to sustain or increase ice melting during stadial cooling.

In a previous study, we were able to simulate warm stadial summers in Europe during the YD with a high-resolution version of CESM1. However, a solution to the contradictory stadial summer cooling signal in many proxies remained elusive. To classify the type of climate that needs to be reconstructed, we calculated now the continentality of past climate states based on simulations of the period 15 to 9 ka BP. We find that continentality in Europe was generally much higher with shifts to extreme values during stadials. The spatial patterns of European continentality gradients imply westerly flow dominance during interstadials and atmospheric blocking during stadials.

We show that an ensemble of climate reconstructions located south of EIS using chironomids and plant assemblages can reproduce warm stadial summers when continental trainingsets are used. A direct proxy-based reconstruction of continentality confirms simulated values of a highly continental Europe. While vegetation-based coexistence likelihood estimations of Lateglacial summer temperatures show a small dependency on the trainingset, chironomids are highly sensitive to continentality. Due to a much higher signal-to-noise ratio of the ensemble mean, we are now also able to reconstruct the Intra-Bølling and Intra-Allerød Cold Period (IBCP, ~14.2 ka BP during GI-1e?; IACP or Gerzensee-Oscillation, GI-1b, 13.2 ka BP) in S-Sweden.

Geochemical data in the Varved sediment database (VARDA): improving the temporal accuracy and resolution of environmental reconstructions

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After launching the Varved Sediments database (VARDA) in 2020 (Ramisch *et al*., 2020), our team has started to collect, harmonize and add geochemical proxy-data from annually-laminated (varved) lakes. The main goal of this exercise is to provide accessible and interoperable data to the paleoclimate and modelling communities, with the specific aim of generating sub-decadal proxy records. Two types of geochemical data have been collected: 1) major elemental composition of (crypto)-tephra layers (Beckett *et al*., in prep.) and 2) stable oxygen and carbon isotopes measured on lake carbonates. The datasets cover the past 35 kyrs with temporal resolutions ranging from 1 to 100 yrs (isotope records). The proxy-records and descriptive metadata were stored in a Neo4j graph database that can be cloned and run locally or accessed via web interface. We collected records from ca. 20 lakes located mostly in Europe and we plan to include lakes from other regions where varved sediments have been identified. Collection and curation of geochemical data of tephra layers is supported by an ongoing PAGES Data Stewardship Scholarship.

Geochemical fingerprinting of tephra layers will enable users to synchronise records with a high temporal accuracy and a better control on tephra attribution (i.e., using both chronological and geochemical information). Stable isotope data obtained on various types of carbonates (biological, authigenic, bulk) will allow users to explore, for instance, the drivers of isotopic fractionation in lake waters at a regional scale. With this contribution, we encourage the wider community to participate in the development of VARDA as well as in data mining and curation. Potential new developments include the addition of other isotope proxies (e.g., deuterium isotopes), bulk geochemistry (e.g., X-ray fluorescence) or pollen data, as well as improving the spatial resolution by adding new locations (including marine varved sediments).

A new varve chronology for the deglaciation of the South Wales sector of the British and Irish Ice Sheet: Implications for glacier and palaeoclimate reconstructions.

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Continuous records of palaeoenvironmental and palaeoclimatic change during the Last Glacial-Interglacial Transition (LGIT) from the British Isles are confined to the last 15 ka and do not record the early phases of deglaciation. The chronologies for the deglaciation of the British Irish Ice Sheet after the LGM have been constructed using radiocarbon, OSL dating and cosmogenic radionuclide dates and retreat rates inferred from Bayesian age models. The potential of annually resolved records have yet to be fully explored in the UK. Three glaciolacustrine varve chronologies from the late Dimlington Stadial (GS-2) are available and these short, floating records provide decadal-scale resolution for transient changes in the ice margin position. However, the spatial extent of UK varve archives requires improvement and the floating chronologies to be linked to absolute timescales. This paper presents the first varve chronology for the LGIT in the British Isles from Llangorse Lake, south Wales, that provides a new age estimate for the deglaciation of the southern part of the British and Irish Ice Sheet and yields new insights into palaeoclimate variability during this period.

Microfacies work has produced two varve chronologies from cores extracted from the extant lake and were merged to create a master varve chronology, which has a total duration of 3505 ±143 years. This chronology is anchored to an absolute age scale at the upper end of the varve section using radiocarbon dates and extrapolating the Bayesian age model to date the onset and end of varve formation. The varve data suggests that initially an ice-dammed glacial lake formed at 19.16 cal. ka BP that transitioned into a cold climate lake system around 19.08 cal ka BP. This nival lake persisted for ~3400 years until 15.66 cal. ka BP, after which the lake transitions to non-varved sediments. Variability observed in the varve thickness record is postulated to relate to inter-annual to decadal variability in hydroclimate with three multi-decadal periods of decreased varve thickness below the record's mean. These periods may reflect periods of reduced precipitation in South Wales during the deglaciation of the British Isles.

Session 98: Past vegetation dynamics and their role in climate change

Mapping Holocene Radiative Forcing from Land Cover Change

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Climate-vegetation feedbacks depend on biophysical land cover characteristics such as albedo. This measure of surface reflectance impacts the surface energy balance. However, the narrow temporal extent of direct observations of albedo make it difficult to quantify centennial to millennial scale shifts. Albedo is used to quantify terrestrial ecosystem processes; its magnitude and variability moderate terrestrial biosphere and atmosphere interactions. Networks of fossil pollen data offer an observational constraint on biophysical land cover change that extends throughout the Holocene. We reconstruct Holocene albedo and associated radiative forcing for North America. First, we estimate average monthly blue sky albedo over the 2000-2009 period from MODIS satellite reflectance data products and ERA5 atmospheric reanalysis diffuse and direct radiation. Blue sky albedo –sometimes referred to as actual albedo– represents the overall surface reflectance from combined direct and diffuse incoming radiation. Then using a spatio-temporal network of fossil pollen records and the derived blue sky albedo, we reconstruct albedo. This reconstruction is done in two steps: calibration and prediction. In the calibration step, we develop a statistical model that characterizes the relationship between modern pollen samples and seasonal albedo. In the prediction step, we apply this model to reconstruct albedo from historical pollen records. Finally, these albedo reconstructions are translated to spatio-temporal estimates of radiative forcing using a pre-industrial radiative kernel. This allows us to identify regions that have undergone land cover shifts that have resulted in warming or cooling. This work provides new insight about the nature of climate-vegetation feedbacks and ecotone shifts, and an empirical constraint on ecosystem forecasts.

LegacyBiome 1.0: A global dataset of pollen-based mega-biome reconstructions covering the last 22000 years

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LegacyBiome 1.0 is a new dataset of global mega-biome reconstructions for the last 22,000 years that is particularly designed for the comparison with Earth System Model simulations. With a standard biomization approach we translated pollen data from LegacyPollen 2.0 - a global taxonomically and temporally standardized fossil pollen dataset of 3728 palynological records (3409 in the Northern Hemisphere, 319 in the Southern Hemisphere) - into mega-biomes for 45 time-slices throughout the last 22,000 years with a temporal resolution of 500 years. These mega-biomes have been adapted to the categories used to biomized Earth System Model results so that reconstructed mega-biome estimates can be directly compared to simulations. The accuracy of the new global biomization scheme was determined by comparing the reconstructed mega-biome distribution with the modern potential natural vegetation pattern derived from observations. Then, the distributions of pollen-based mega-biomes were compared against an ensemble of model simulations for the last deglaciation. The overall global mega-biome trend in the reconstruction is in line with the simulations, even if differences are visible at the continental scale. This set of model-based and reconstructed biome trajectories is used to infer the rate of vegetation changes and the stability of the vegetation dynamics on a regional scale. We are now able to identify regions with the greatest disparity between Earth System models and reconstructions, including the Southern Hemisphere, and to discuss better possible reasons for model-data mismatches based on regional characteristics.

Reconstructing biome changes on the Tibetan Plateau since the Last Glacial Maximum using a machine learning method

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Tibetan Plateau (TP), as the world's largest plateau, has received much attention on the dynamics of its alpine ecosystems under changing climate. Exploring the historical biome changes on the TP can extend our knowledge of the long-term response of alpine vegetation to climate change. However, the comprehensively quantitative reconstruction of the past TP biomes is not available due to the lack of suitable methods that enable appropriate classification of alpine biomes based on proxy data such as fossil pollen records. We developed a pollen-based biome classification model by applying the random forest algorithm (RF, a supervised machine learning method) based on modern pollen assemblages from the TP and its vicinity (n=1764 sites), and its robustness was assessed by comparing its results with the predictions of the biomisation method. The results indicated that modern biome distributions reconstructed using the RF model based on modern pollen data were in generally good agreement with the observed zonal vegetation. Moreover, the RF model showed a significantly higher accuracy than the biomisation method, indicating the former is a more suitable tool for reconstructing alpine biome changes on the TP. The RF model was then applied to reconstruct the biome changes on the TP over the last 22 ka based on 51 fossil pollen records. A series of biome maps of the TP was constructed at 500-year intervals, and five stages reflecting the major changes in biome pattern since the Last Glacial Maximum (LGM) were recognized, which generally corresponded to contemporary global climate changes and Asian monsoon variations. TP was primarily dominated by deserts with subtropical forests distributed in the southeast in the LGM. During the last deglaciation, the alpine steppe began expanding and gradually became zonal vegetation in the central and eastern regions. Alpine meadows occupied the eastern and southeastern TP since the early Holocene, and the forest-meadow-steppe-desert pattern running southeast to northwest on the TP was established afterwards. Subtropical forests extended north in the mid-Holocene, which reflected the "optimum" condition. During the late Holocene, alpine meadows and alpine steppes expanded southwards at the expense of forest.

Vegetation representation of modern pollen assemblage and long-term change of plant diversity in Nam Co catchment, central Tibetan Plateau

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Pollen diversity offers abundant clues into the floristic diversity and history of vegetation change. Few palynological studies investigated modern pollen diversity or the past floristic diversity on the Tibetan Plateau (TP). Based on modern pollen assemblages from 37 topsoils and 63 surface lake sediments in the Nam Co catchment on the central TP, this study quantitatively explored vegetation representation of modern pollen assemblages and spatial distribution of modern pollen diversity using Shannon-Wiener index (H) and palynological richness (E(Tn), n=600). Modern pollen assemblages from topsoils of different vegetation had diagnostic features in terms of composition and pollen percentage. The results of boosted regression tree analysis confirmed that source vegetation was the predominant factor (85.8%) responsible for the vegetation representation of lacustrine pollen assemblages, while sedimentary processes accounted for only 14.2%. The results of discriminant analysis indicated that most lacustrine pollen assemblages (90.5%) were representative for the regional vegetation of alpine steppe in the catchment and central TP, while only 9.5% were representative for the local meadow vegetation. Pollen diversity indices showed spatial variability among vegetation types (high values in the domain of alpine steppe, while low values for meadow), reflecting the differences in terrestrial floristic diversity. Therefore, pollen diversity in lacustrine pollen assemblage could be an effective proxy to document past floristic diversity. The past floristic diversity in the lake catchment, recovered from a fossil pollen record of NMLC-1, showed a long-term change of ascending overlaid by several rapid diversity changes during the last 8400 years. This could be attributed to the downward shift of altitudinal vegetation belt driven by a general climatic cooling. The results imply that under the environmental challenge of climate warming and vegetation degradation, alpine vegetation restoration in the central TP should pay attention to altitudinal vegetation belts.

Holocene fire regimes in the Eurasian boreal and boreo-nemoral forest: the first-continental assessment based on charcoal data

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The Eurasian boreal forest extends over ~15 M km^2. The composition of these forests is spatially heterogenous; the dominant tree species in Europe is distinctly different from Siberia. Fire regimes in Eurasian forests are diverse, but modern fire records are too short to capture patterns, trends, feedback, and drivers of variability. Charcoal records identified from sediment provide valuable perspectives on the centennial to millennia fire regime. Considerable efforts have been made in recent years to fill some gaps in our understanding of the past changes in wildfire regimes; however, the Eurasian boreal region, particularly in Siberia, needs major improvement. Here, we present the first assessment of changes in wildfire regimes, the timing, and drivers of the significant shifts in fire regime during the Holocene at the boreal Eurasian scale based on macrocharcoal records from Europe, Siberia, and subregions within. We found noticeable differences in the Holocene trends and mean fire return intervals among regions in Eurasia. On a Holocene scale, recent fire frequency and severity exceed the long-term Holocene trends or those recorded over the last 4500 years over Eurasia and all its regions except boreal Fennoscandia. At the spatial scale, Europe recorded higher fires and shorter fire rotation than Siberia. In Europe, the mean fire frequency increased along the west to the east gradient from boreal and boreo-nemoral Fennoscandia to European Russia. In Siberia, the mean fire frequency rises slightly from the west to central Siberia. Ongoing analyses indicate that shifts in fire regimes follow trends in large-scale climatic conditions, the dominant tree species composition, and their fire-related traits. The insights will improve our understanding of how Eurasian fire regimes might respond to future climate changes and evaluate the potential of boreal and boreo-nemoral forests to adapt to new fire regimes.

The reconstruction of Holocene spruce migration dynamics in NE Poland using the REVEALS model

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The presence of Norway spruce [Picea abies (L.) Karst.] in north-eastern Poland, in the border zone between the oceanic and continental climates of its boreal range, suggests that even minor, or short-term climate changes in this region may cause (and could have in the past) an increase in the area covered by spruce when changes are favourable (cooling and/or increase in climate humidity) or its decline when changes are unfavourable for this species (warming and/or drought).
The objective of the research was to investigate whether a transient spread of Norway spruce in the late Holocene, reflected in the pollen records from four lakes in north-eastern Poland (Suchar Wielki, Suchar II, Jezioro Ślepe and Szurpiły), resulted from human activity, or whether this process was caused by short episodes of climate cooling dated at about 4200, 3400 and 2800 cal. yr BP. By using regional estimates of vegetation abundance (REVEALS) with reference to palynological data from the investigated lakes in north-eastern Poland, it was possible to reconstruct changes in vegetation in the studied area at chosen intervals. This is important in studies on the succession of spruce, which, because of its heavy pollen grains, may be poorly represented in pollen spectra from lakes, despite the fact that it is found in quite large amounts in the forest communities of the studied region.
The developed model of vegetation cover showed that the expansion of spruce in the studied region correlates very well with the short episodes of climate cooling and increased humidity dated at 4300-4100 and 3500-3300 cal. yr BP. However, contrary to previous expectations, the succession of spruce was inhibited during the climatic oscillation between 2900 and 2700 cal. yr BP. At the same time, anthropogenic plant communities developed during that period, which was associated with settlements of the West Baltic barrow culture at the end of the Bronze Age and the beginning of the early Iron Age.
This study was supported by the National Science Centre (M.F., 2019/03/X/ST10/01114).

Neotropical tree cover response to variation in post-Last Glacial Maximum climate and atmospheric CO2

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The post-Last Glacial Maximum period (~ last 19,000 years) was characterised by major changes in the global climate and atmospheric CO_2 concentration. In the Neotropical realm, scattered palaeoenvironment records suggest multidirectional and asynchronous tree cover changes among regions. Local chronological comparisons between vegetation and climate archives suggest that changes in moisture availability during the deglaciation period could be the main forcing. However, the scale and processes of Neotropical tree cover response to post-Last Glacial Maximum climate changes remains cryptic. Here, we modelled the evolution of tree cover throughout this period using the dynamic global vegetation model LPJ-GUESS forced with seven realistic general circulation model palaeoclimate experiments (Last Glacial Maximum, Heinrich Stadial 1, Younger Dryas, Greenlandian, Northgrippian, Meghalayan, and the present). Our high-resolution simulation results (0.5° x 0.5°) are generally consistent with palaeovegetation records and suggest that the average potential tree cover in the Neotropical realm steadily increased from the Last Glacial Maximum (30%) to the present (44%). Variation in climate and atmospheric CO_2 seem responsible for substantial, widespread, and asynchronous increases in tree cover in all regions, which may have strongly affected about a third of the Neotropical realm. In addition, patterns of tree-cover are sensible to variation of intensity and position of the intertropical convergence zone, the South Atlantic convergence zone, and southern westerly winds, which confirm the implication of precipitation changes in Neotropical vegetation evolution throughout the post-Last Glacial Maximum period.

Vegetation and climate changes of the East-European forest-steppe during the last 15,000 years

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Climate change is one of the greatest problems facing humanity. One of the economically important areas potentially threatened by the warming is the East-European forest-steppe ecotone. Located between arid steppe and mesophilic forests, the ecotone combines the most favourable soils and climate conditions for crop production. Higher temperatures change this balance and induce higher risks for agriculture in the region. Palaeoecological studies reflect vegetation changes through time and allow to predict vegetation reaction to climate change. We studied several sediment cores obtained in a north-south gradient across the forest-steppe in the Kursk (Russia) and Kharkiv (Ukraine) regions. Multi-proxy studies including palynology, charcoal, loss-on-ignition and botanical macro-remains' analysis were carried out on these cores. Combining all available records, we reconstruct the forest cover using the modern analogue technique and evaluate possible shifts in the southern treeline and the character of the ecotone since the postglacial. With the use of transfer functions, we explore potential climate forcing that may have changed the vegetation of the ecotone. According to our results, if the current climate warming reaches the Holocene thermal maximum, it might favour arid steppe vegetation and induce risks of drought for agriculture in the region.

Session 99: Lipid biomarkers as molecular archives of human activity from archeological sites

Paleoenvironments and past human activity at the prehispanic cave of Las Estacas (Canary Islands, Spain): A lipid biomarker study

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Combining lipid biomarkers with compound-specific stable isotope analysis (CSIA) in archaeological sediments provides information about past human activity and their environment. Las Estacas rock shelter (Canary Islands, Spain) is an aboriginal archaeological coastal site with evidence of occupation for the last 1500 years. The cave deposit comprises natural (light brown silts) and anthropogenic (combustion structures or hearths) sediments. We carried out gas chromatography-mass spectrometry (GC–MS) and gas chromatography–isotope ratio mass spectrometry (GC–IRMS) analyses to investigate the natural sedimentary sequences and their correlated combustion structures. Our molecular (*n*-alkane, aromatics, ketones, alcohols, and fatty acids) and isotopic ($\delta^{13}C_{alkanes}$, $\delta D_{alkanes}$, $\delta^{13}C_{16:0}$, and $\delta^{13}C1_{8:0}$) analysis allowed us to reconstruct the paleoenvironmental context and assess landscape anthropogenic transformation, as well as to provide clues about human behavior.

Combined application of lipid biomarkers and soil micromorphology to reconstruct indigenous pastoral activities at the Buracas Cave Complex (La Palma, Canary Islands)

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Pastoralism constituted a main subsistence activity among the indigenous populations of the Canary Islands, especially in islands with an abrupt terrain that difficulted the development of agricultural practices. In the case of La Palma, the northwesternmost island of the archipelago, recent archaeological studies indicate that indigenous herders mainly occupied natural caves and rockshelters, leading to the formation of dung deposits inside the cavities. Lipid biomarker analysis focused on steroids has shown great potential to discriminate animal faecal input, and thus, livestock composition. Sedimentary *n*-alkanes can be used to identify plant sources; and in dung deposits, they can shed light on herd diet composition. Combining this approach with soil micromorphology contributes data on the microstratigraphic context. Here, we report preliminary results from a microcontextual geoarchaeological analysis conducted at the Buracas Cave Complex (north of La Palma), a set of volcanic rockshelters occupied during pre-European times. Micromorphological analysis of the studied sequence indicate a sequence of ovicaprine stabling events and episodic burning typical of *fumier* deposits. The lipid biomarker data allows us to identify the origin of the faecal matter and the plant sources used as livestock fodder.

Spatial heterogeneity of biogeochemical properties as a reflection of functional zones within the cultural layer at Upper Palaeolithic site Zaraysk, East European Plain

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The impact of Palaeolithic humans on Pleistocene ecosystems has been considered insignificant due to their low population, non-sedentary lifestyle, and hunter-gatherer activity. However, within settlement the anthropogenic pressure could have been substantial enough to be imprinted in ‘soil-memory’ and variable enough for differentiation of several types of settlement activities, which enables the determination of functional zones within cultural layer through distinctive biogeochemical signatures related to human everyday activities.
The Eastern Gravettian cultural layers at the Upper Palaeolithic site Zaraysk date back to 23-16 uncal ka BP. Various functional zones were sampled: bottom of a flintknapping waste disposal pit, bottom of a hearth, floor of an earth-dwelling structure, surface of a cultural layer, and a reference sample of the contemporary Zaraysk palaeosol from the peripheral area of outside the settlement. To determine the signature of anthropogenic activities and their spatial heterogeneity, we analysed biogeochemical (C/N, biomarkers) and geochemical (elemental composition) data. The results indicated the significant difference between functional zones and the concentration of non-leaf wax-derived organic carbon was calculated, which within the cultural layer was interpreted as a consequence of the anthropogenic activity.
The research was financially supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany´s Excellence Strategy – EXC 2150 – 390870439, RFBR (no.19-29-05267), RSF (no.19-18-00327), NIOKTR 122011200271-7.

A micromorphological and lipid biomarker characterization of the Late Pleistocene sediments of Cave of the Skulls (Israel)

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In recent years, advances in biomolecular analyses applied to archaeological research, offer promising insights on climatic-driven hypotheses that can now be addressed with high-resolution paleoenvironmental proxies. Leaf wax carbon and hydrogen isotopic compositions from natural dung deposits, such as those from hyrax middens are key for inferring the palaeoclimate history of a locality or region. Moreover, the integration of these analyses with microstratigraphic analyses, as soil micromorphology, provides robust characterisation of site formation and of post depositional processes that could be affecting the organic remains.
Recently, new research has pointed out an increase in effective moisture during MIS 4 and 3, and ecological modelling has suggested that the Judean Desert was greener in the past. Here we analysed soil sediments and *Hyracoidea* dung pellets from the Cave of the Skulls stratigraphic archaeological sequences in order to elucidate the abrupt, millennial-scale climate oscillations of the last glacial period, also known as Dansgaard-Oeschger cycles, in the Judean Desert. This multi-proxy approach includes 1) soil micromorphology, 2) *n*-alkane hydrogen and carbon isotope ratio analysis, and 3) faecal sterols and bile acids. The results add new data regarding plant water stress, precipitation and aridity, and detect possible shifts in hyrax diet composition during the last glacial period.

Biomarker evidence for the construction and occupation of crannogs in Scotland and Ireland from lake sediment records

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Crannogs are artificial islands constructed in lakes and wetlands across Scotland and Ireland from the Iron Age to the Medieval period. Excavations of partially or fully submerged crannog structures are logistically and financially challenging, therefore the timing of crannog occupation and function remains poorly constrained. We present analysis of lake sedimentary archives adjacent to crannog structures as an alternative approach to excavation, to establish construction and occupation histories at two sites: Lough Yoan (N Ireland) and White Loch of Mytron (SW Scotland). Our data provide direct anthropogenic evidence using steroid biomarkers contained within wetland/lake sediments. Evidence of human faecal matter is identified at both sites, demonstrating preservation of faecal steroids within sedimentary environments. The ability of these steroids to provide direct evidence of human occupation is supported by occupation dates independently obtained from archaeological excavations. Steroid ratios indicate the presence of ruminants within the settlements, which is confirmed by sedimentary DNA (*seda*DNA) analyses and supported by palaeoecological-derived nutrient-driven changes in aquatic ecology (diatoms and chironomids). The similarities between faecal steroid records and independent lines of chronological and palaeoenvironmental evidence highlights the ability of lipid biomarkers to provide direct evidence of human occupation from lake sediments, but also demonstrates the ways in which these analyses can be used to characterise occupation phases and advance interpretations of wetland archaeological sites.

Lipid biomarker for diet identification and palaeomagnetism perspective

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El Portalón de Cueva Mayor is an archaeological site in the UNESCO World Heritage Centre of Atapuerca (Spain) with a Holocene stratigraphic sequence attributed from the Neolithic to the Roman period. Along these chronologies, this site was used for different purposes: i) habitational where archaeological assemblage shows a mixed economy with similar roles of farming, hunting and gathering strategies; and ii) funerary, due to the presence of tumulus and human remains. Pottery sherds are the main finds, with lithics, faunal remains or metal artefacts.

In this contribution, we present results from lipid residue analysis in pottery samples from different chronologies: Neolithic (*ca.* 5320-3670 cal. BCE), Chalcolithic (*ca.* 3080-2480 cal. BCE) and Bronze Age (*ca.* 2290-1220 cal. BCE), to study changing diet in ancient populations. To address this research question, a total of 104 pottery sherds were originally studied by chromatographic and spectrometric techniques to assess the presence of lipids in samples and characterise the biomarkers. Archaeological lipids were detected in 53 samples and identified as coming from animal fats. Compound-specific carbon isotope analyses was used to identify the source of those animal fats, with the detection of mainly dairy fats and ruminant and non-ruminant carcass fats, in all analysed chronologies.

Milk is one of most impactful food consumption in today's society, since it has been "only" consumed for a few millennia. aDNA analyses carried out in El Portalón shows that the population in Neolithic was lactose intolerant, while but this study reveals the presence of dairy products in pottery.

In order to study the cooking processes, we study for the first time the palaeomagnetic signal within the pottery clay. Using this method, we have identified pots that have been heated up only once (firing) from those that present a firing + cooking signal. This novel approach opens up new avenue of investigation regarding cooking techniques.

Biomolecular evidence for Neolithic cuisine in the Kashmir Himalayas and its potential to support future mountain food security

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Recent archaeobotanical evidence from the Kashmir Valley in the Western Himalaya indicates the cultivation of West and East Asian cereal crops and pulses by as early as 4400 BP. At present, little is known about the processing or consumption of these plant foods, while the lack of published comprehensive zooarchaeological data limits our understanding of dairy or meat consumption. For the first time, we present the results of biomolecular analyses performed on absorbed residues from Early and Middle Neolithic ceramics from the Kashmir Valley, dated between ca. 4200-3500 BP. These data are compared with modern experimental references, as well as the archaeobotanical record to interpret patterns of food production and consumption through the Neolithic period in the valley. Palaeoclimate data has characterised this period as one of shifting precipitation regimes and climate instability, following a warm-humid Middle Holocene. We argue that drawing on 'deep time' data from the past, particularly in relation to "neglected" or underutilised food resources, may provide avenues to support food securities for Himalayan populations as they respond to projected climate instabilities in the future.

Identifying the use of marine resources: can shell and shellfish lipids help?

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Use of marine resources is attested for prehistoric populations since Neanderthal times. The use of large heaps of shells (so-called shell middens) specifically is first associated with early Modern Humans, but most frequently encountered in Mesolithic and Neolithic contexts, in Atlantic Europe and across the globe. The use of marine resources in general, is regularly documented in early pottery vessels from coastal contexts in Eurasia. Understanding the use of specific marine resources such as shellfish consumption, and shell use in constructions and hearths, is however limited. Not much work has been done on biogeochemical signals, such as lipid biomarkers, of specific marine resources.

In this exploratory study, we analysed local Canary Island shellfish (*Patella ulyssiponensis*). Our research questions are: what lipids do we find in respectively shells and shellfish? Can we characterise the fatty acids, and distinguish them from other marine animals? Thirdly, what is the effect of burning on the lipid composition and quantity in both shells and shellfish? In this presentation we will give first results of this analysis and provide insights into identifying the use of these specific marine resources, in coastal sediments, combustion features, and pottery.

Session 100: Multi-methods geochronological approaches on Palaeolithic sites

Magnetism meeting radioactivity: Lessons from Atapuerca

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The oldest hominid migrations out of Africa into Europe is a controversial debate topic that has ignited heated arguments for several decades. In the northern *plateau* of the *Iberian* Peninsula, the archaeological and paleontological site of Atapuerca is a key locality to contribute to the conundrum, as it holds evidence for the most complete and oldest record of human presence in Eurasia as of today. As such, solid chronologies of both fossils and deposits are of paramount importance to contextualize the hominids within the models of human dispersal into the continent. We will focus on the “Trinchera Atapuerca” sites, a complex of karstic caves developed in Cretaceous limestones partially filled with sediments of both fluviatile and slope origin. The slope deposits, traditionally known in the literature as “entrance facies”, are notorious for containing a rich record of both hominid fossils and lithic tools. Stratigraphic layer TD6 of Gran Dolina has yielded over 170 human fossil remains, more than 200 lithic artifacts, as well as several thousand small and large vertebrate remains. Since 1995, with the discovery and dating of hominid fossils older than the Matuyama-Brunhes reversal (0.78 Ma), numerous studies have progressively provided insights and further refinements on the age of both the fossiliferous and the sterile deposits in Atapuerca. A key issue in the advancement and reliability of the chronology has been the systematic use of complementary dating methods, including paleomagnetism, electron spin resonance (ESR), luminescence (OSL), terrestrial cosmogenic nuclides (TCN), and uranium-series. Each method depends on the available material in the sediments as well as the expected age range. The combination of these geochronology methods allows comparing depositional versus burial ages. The paleomagnetic signal provides the record of the magnetic field at the time of the sediment deposited. On the other hand, exposure and charge particles methods in cave environments, provide the age of the last sunlight exposure of quartz (or feldspar) grains before they were introduced into the cave. Altogether, the current results provide a solid record of human presence in Atapuerca-Trinchera encompassing at least 1.2 Ma, becoming a landmark for the oldest migration pulses into Europe.

Multiple protocols - luminescence dating of the Middle Stone Age deposit at Sibhudu rock shelter (South Africa).

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Sibhudu rock shelter preserves one of the major sequence, over four meters thick, of Middle Stone Age artefacts in South Africa, uncovering pre-Still Bay, Still Bay, Howiesons Poort, and Sibhudan techno-complexes. The first optically stimulated dating chronology performed on single quartz grains by Jacobs et al. in 2008 and 2017 indicated ages between 38 to 72 ka.

While the continuing excavation has uncovered deeper layers, the whole sequence has been re-sampled for optical dating. We applied several protocols on single or multiple grains aliquots of quartz or potassium feldspar grains, including SAR, IR50, pIR-IR290, pIT, and RF[1] , in order to improve and extend the final chronology. Here we show that, other than the RF ages, which overestimate the mean of other age estimates by over 30%, ages for the various protocols are usually within 10% of their mean. Although the excavation has not yet reached bedrock, our results have extended the chronology of Sibhudu back at least until late Marine Isotope Stage 6.
[1] SAR : single aliquot and regenerative dose, IR50: infra-red at 50°C, pIR-IR290: infra-red at 290°C post infra-red at 50°C, pIT: Infrared post isothermal annealing, RF: radiofluorescence.

Geological and geochronological reconstitution of the Cagayan Valley (Luzon Island, Philippines)

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The Paleolithic site of Kalinga, in the Cagayan River basin in the Philippines, is associated with the oldest known human occupation traces of the archipelago and dated to 709 ± 68 ka by our research group. This work presents the geomorphological and geochronological study carried out in the region of the site. After the discovery of several surfaces paleontological remains and lithic productions, the region was the subject of numerous excavations from the 1970s, but the chronological framework remained to be specified. In the 2010s, on the Kalinga site, lithic tools and a rhinoceros carcass showing butchery traces were discovered undisturbed in the sedimentary levels, dated afterwards by our team in 2019. Despite these dates, the geomorphological and geochronology of the area are still little known. This work aims to clarify them through the use of ESR dating methods on quartz and $^{40}Ar/^{39}Ar$ on plagioclase. The sedimentary deposits of the Cagayan Basin are mainly composed of fluvial sands partly formed from minerals of volcanic origin. This composition allows the application of these two absolute dating methods. Our results reveal a human occupation between 900 and 400 ka. From a geodynamic point of view, this period is marked by intense tectonic activity with the compression of the structural layers of the sedimentary basin between the two mountain ranges that surround it, the Sierra Madre to the east and the Cordillera Central to the west. This compression resulted in the basin layers folding, causing the appearance of anticlines. The results obtained make it possible to hypothesize a change in the Cagayan River flow direction about 600 ka ago connected to the folding. The latter is supported by the absence of feldspar crystals from later ages as well as the presence of seismites.

40Ar/39Ar dating applied to archaeology: what is new?

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The dating of volcanic material including ash layers and lavas using $^{40}Ar/^{39}Ar$ radio-isotopic method is characterized by major technical and technological improvements over the last 10 years which improved both the precision as well as the accuracy of the produced dates. The latest mass spectrometers equipped with high sensitivity multicollectors allow now to date smaller and/or younger K-rich material with precision and accuracy previously unreachable. It is now common with the $^{40}Ar/^{39}Ar$ method to challenge and even in some case improve the accuracy of the radiocarbon dating in the 30-50 ka range period (e.g. Giaccio et al., 2017; Albert et al., 2019) but also to date single 250 microns K-feldspars that are less than 200 ka (e.g. Monaco et al., 2022).

We will take examples of recent investigations to illustrate the new possibilities that are now offered to archaeologists working in geographic areas where volcanic materials could be found together with lithic tools, fauna or human remains. These examples will cover the last 1.8 Ma and will concern various archaeological contexts. Moreover, these cases will illustrate a large part of datable material including K-Feldspars, Plagioclase, lavas, obsidian as well as tektites.

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The first hominin occupation of Central Europe: Cosmogenic nuclide cross-dating with paleomagnetic records at Korolevo I, western Ukraine.

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Early hominins are known to have reached western and southern Europe by the Early Pleistocene, but their first appearance elsewhere in Europe is still uncertain due to the lack of solid evidence, as well as the lack of securely dated basal Palaeolithic sites. Korolevo I located in Transcarpathia, western Ukraine, is among the most well-documented, deeply stratified archaeological sites in Europe, with hominin occupation spanning the Early to Upper Pleistocene. At the locus of Gostry Verkh in Korolevo I, the 12m-thick loess-palaeosol profile XIII contained stratified in-situ artifacts from multiple cultural layers spanning the Lower to the Upper Palaeolithic. The site was extensively excavated since 1975, but the Korolevo I chronology remains debatable, particularly below the Brunhes-Matuyama boundary at 7.5 m, with a possible Jaramillo subchron at 10.7 m. Here we constrain burial age of the lowermost artifact level VII (at 11.1–12.0 m) by using in-situ cosmogenic nuclide ^{10}Be and ^{26}Al. Nine cobbles made from vein-quartz, quartzite, and fine-grained sandstone of the level VII were obtained from the collection of Transcarpathian Palaeolithic expedition 1985. The cobbles of high variability (weathering, lithology, mass) went through a challenging quartz purification and Be/Al separation process. The assay of in-situ cosmogenic nuclides ^{10}Be and ^{26}Al was obtained by the Accelerator Mass Spectrometry, followed by numerical modelling of the most probable burial age. Our cosmogenic nuclide burial dating results at Korolevo I are consistent with palaeomagnetic data obtained by previous researchers and represent the earliest securely dated early hominin site in Central Europe. These new dates not only establish the lower layers of Korolevo I as one of the earliest hominin settlements in Central Europe, but also within the same chronological stage reported from southern and western European sites. This research provides critical spatiotemporal data for the paleogeographic scenarios of an early hominin dispersal in Europe and highlights the need for more research in this under-served region.

The significant but little-known Lower Palaeolithic Belle-Roche site (E. Belgium) assigned to MIS 12-11 by a combination of U-series, electron spin resonance (ESR) and single-grain thermally-transferred luminescence (TT-OSL) dating methods

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Although the Belle-Roche site located in the Ardenne Massif (E. Belgium) was unearthed in the early 1980's, its significance in terms of archaeology and palaeontology has remained somewhat unnoticed by the scientific community. This small, fossilised cave is perched ~60 m above the Amblève's current floodplain, i.e. the main sub-tributary of the Meuse River. The 3.5 m-thick sedimentary infill of this karst system consists of fluvial pebbles and sands overlain by 2-2.5 m-thick, coarse-grained slope deposits. Whereas the former are archaeo-palaeontologically sterile sediments, the latter embed no less than 50 different taxa of macro-faunal remains through the entire sequence. These primarily comprise large mammal carnivores such as *Canis mosbachensis, Panthera onca gombaszoegensis, Panthera leo fossilis and Ursus deningeri*, but rodents such as *Arvicola cantiana* are present as well. Equally important is the finding of more than 100 lithic tools at the top of the slope deposit sequence. Due to the lack of their sophistication, these bifaces, choppers and scrapers (along with deep angular notches in bones interpreted as cut-marks) were assigned to a primitive Palaeolithic industry, possibly the Acheulean.

Despite some useful relative (palaeomagnetism) and correlative (biochronology) age constraints on the site and numerical dating of a nearby fluvial terrace (by cosmogenic nuclides), neither the fossil-bearing layers nor the archaeo-palaeontological remains have been numerically dated; likely explaining why this site has remained little-known. Here, we aim to fill this gap by firmly dating this site in a twofold manner. First, fossil bones and teeth from selected large-mammal remains were sampled for U-series and combined U-series/Electron Spin Resonance (ESR) dating, providing consistent age estimates of around 400-450 ka. Second, both basal fluvial sand and the slope deposit fine-grained matrix were sampled for extended-range luminescence dating (single-grain TT-OSL and pIR-IRSL). Analyses are currently ongoing but the preliminary results confirm the status of the Belle-Roche site as a reference for mammal association in NW Europe during MIS12-11 and provide firm constraints on MIS11 human occupation of this region (i.e. oldest site so far in Benelux).

EQuaTe: a European Quaternary Timescale for the expansion and evolution of humans

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The Quaternary geological, palaeontological and archaeological records in Europe are the most extensively studied in the world, providing a detailed history of the climatic and environmental changes critical to understanding our human story. However, most of the key terrestrial sequences are short, recording only snapshots of time which have little meaning without a securely dated independent timescale. This severely limits our understanding of when early humans may have migrated into and adapted to early European environments, and the effects on their cognitive developments and cultural identities. Differences in tool technologies could be telling us about use, technical evolution, source material, populations or even species differences, but without a secure chronology to tie the archaeological sites together, these fundamental questions cannot be addressed properly.

To help resolve these problems, the EQuaTe project is building on recent discoveries that fossil biominerals provide coherent time signals trapped within their crystals. Commonly-occurring calcitic fossils (snail opercula) provide both closed-system repositories for amino acids (AA) and a stable thermoluminescence (TL) signal that can date events over at least the last 2.6 Ma. We are therefore using both dating methods (AA and TL geochronology) on the same biominerals from a range of archaeological and palaeontological sites to build a dating framework across Europe. Our selected study region ranges from the British Isles to the East European Plain, bounded by the Pyrenees, Alps, Caucasus and Urals; this covers a region beyond potential refugia, where human populations would have been dynamic and highly adaptive, and for which repopulation could have been from different regions. Opercula are often abundant in sediments in this region so form the main study target, but we are also exploring the potential of other biominerals (e.g. tooth enamel, slug plates, worm granules, foraminifera) to expand the environmental scope of the techniques. Here we present the datasets from Britain, France, the Netherlands, Germany, Switzerland and Poland, compare them with other evidence of age, and provide the first integration of these regional frameworks for the basis of a pan-European chronology.

Session 101: Integration of palaeoecological proxy data for the reconstruction of climate and environment dynamics

Sub-millennial scale reconstruction of late Quaternary critical zones in Utah, USA using laminated soil carbonate rinds

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Soil carbonate is calcite ($CaCO_3$) that forms in dryland soils worldwide. It has been widely used as a paleoclimate archive on long timescales (>10^5 yr) because its carbon and oxygen isotope composition are related to vegetation and soil water isotopes during the time of formation. Advances in high-resolution techniques now permit paleorecord development from laminated soil carbonates (also called, e.g., coatings, cutans, pedothems, pendants, rinds) on Quaternary timescales (0–2.7 Ma) with data resolution of 10^2–10^3 yr, as demonstrated by studies in the United States (USA), Syria, Turkey, and Siberia. For example, in our prior work, we generated ^{14}C, clumped isotope, $\delta^{18}O$, and $\delta^{13}C$ transects from a southern Utah (USA) laminated rind. The fidelity of the 35–5 ka records of temperature, soil water, and vegetation is supported by prior regional inferences.

Here, we assess how this novel paleorecord type will provide new kinds of information about ancient critical zones. The western USA had large changes in the geographic and elevational distribution of plants and moisture during the last glacial period, but soil responses remain difficult to assess. We are therefore using a suite of six laminated rinds from southern Utah to explore changes to the critical zone over a ≈750 m elevation gradient. Preliminary radiocarbon dates are in stratigraphic order and rinds grew from the last glacial period into the Holocene (<11.8 ka). Six SIMS-based $\delta^{18}O$ transects range from approximately -15 to -5 ‰ VPDB, with individual transects having internal variability between 3 to 10 ‰. We hypothesize that changes in the seasonal timing of soil carbonate formation (e.g., spring to summer) caused the larger $\delta^{18}O$ ranges, as driven by the interplay of temperature, rainfall, soil respiration, and infiltration. Interestingly, however, elevation is a poor predictor of average $\delta^{18}O$ values and $\delta^{18}O$ variability, which may indicate the importance of site-specific controls. These inferences are intriguing, especially in the context of forthcoming carbon isotope and clumped isotope records (proxies for vegetation and soil temperature, respectively), and highlight the sensitivity and heterogeneous responses of dryland critical zones to small changes in temperature and rainfall.

Palaeoenvironmental and palaeoecological reconstruction during Late Pleistocene-Early Holocene in Mesopotamian and Chacoan regions (Argentina): a mammalian stable isotope approach

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Carbon and oxygen stable isotope composition analyses on fossil bioapatite of herbivore mammals allow inferring palaeoenvironmental, palaeoclimatic, and palaeoecological conditions. δ^{13}C values are used to reconstruct the diets of extinct taxa and their preferential habitats, whereas changes in the δ^{18}O values of obligate drinking animals reflect variations in δ^{18}O of meteoric water, which is controlled by temperature and evaporation rate. With the aim to infer these conditions during the Late Pleistocene-Early Holocene in northeastern Argentina, we evaluated a total of 155 tooth enamel and bone samples of representatives from eight families of herbivores: Glyptodontidae, Pampatheriidae, Megatheriidae, Mylodontidae (Xenarthra), Toxodontidae (Notoungulata), Camelidae, Cervidae (Cetartiodactyla) and Gomphoteriidae (Proboscidea). Samples come from the Toropí/Yupoí Formation (Late Pleistocene, Corrientes Province, Mesopotamian Region) and Río Bermejo Formation (Late Pleistocene-Early Holocene, Formosa Province, Chacoan Region).

δ^{13}C values point to the existence of an open environment. Representatives of all families had a preference for mixed C_3-C_4 plant-based diets, including Cervidae that usually show a C_3 plant-based diet. Some individuals of Toxodontidae and Gomphotheriidae retrieved data with a preference for an exclusively C_4 diet, indicating the presence of grasslands in Corrientes and Formosa provinces landscapes. No significant differences have been detected for δ^{18}O values between both Quaternary intervals considered, indicating that all the analysed obligate drinkers may have consumed water subjected to the same temperatures and hydrological conditions. It is remarkable that during the latest Pleistocene-earliest Holocene of Formosa province, Camelidae showed a higher δ^{18}O value than the rest of the families, presenting significant differences particularly with Toxodontidae and Glyptodontidae. Considering that the Camelidae genera here included are *Lama* and *Hemiauchenia* (non-obligate drinkers), we interpret their δ^{18}O values as a reflection of the evaporation conditions of the vegetation and not of the water bodies.

These are the first results of isotope composition applied to mammal communities from the Quaternary of northeastern Argentina. This allows comparisons with other paleocommunities of southern South America to make interpretations on palaeoecological, palaeoenvironmental and palaeoclimatic conditions of the region.

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A one-million-year Molybdenum isotope redox and lake-level record from ferruginous Lake Towuti, Indonesia

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Molybdenum (Mo) isotopes are a well-known redox proxy in marine environments and may record redox changes, mixing, and stratification in lake environments. Here we present a ~1 Myr Mo sedimentary record from ferruginous and hyposulfidic Lake Towuti, Indonesia. Lake Towuti is a tectonic lake up to 200 m deep and is weakly stratified and anoxic below ~100 m depth. We performed a source-to-sink approach targeting ultramafic bedrock, lateritic weathering profiles, 37 lake surface sediment samples, and sedimentary drill core records spanning the past ~1 Myr, to better understand Mo variation in this setting.

Larger variations in [Mo] and $\delta^{98/95}$Mo are observed in the lake sediments compared to the weathering profiles. Mo concentration increases with water depth and distance to major riverine inlets suggesting hydrodynamic sorting and Mo enrichment in fines. $\delta^{98/95}$Mo exhibits a pattern with heavier signatures, similar to the lateritic source, in deep anoxic water and substantially lighter signatures in shallow oxygenated water sites. The $\delta^{98/95}$Mo varies from –1.146‰ to –0.135‰ during the past 30 kyr, with the lowest values during the dry and cold Last Glacial Maximum suggesting enhanced climate-driven lake mixing and deep water oxygenation at the deep water coring site. Sediments deposited during the wet and warm Holocene exhibit Mo isotope signatures similar to present-day anoxic deeper water settings thereby indicating persistent water column stratification. These results suggest the potential of Mo as a redox proxy through time. Over the long ~1 Myr time-span, [Mo] and $\delta^{98/95}$Mo show even larger variability potentially recording basin-wide water depth changes and basin evolution. Our results highlight the versatility of Mo isotope compositions for recording both climate- and tectonically driven changes in physicochemical parameters in lacustrine settings.

Analyses of phytoliths and stable carbon isotopes of modern plants and surface soils from the Bengal region: implications for palaeovegetation and palaeoclimate reconstructions

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Phytoliths and stable carbon isotopic studies have already been proved as effective tools for understanding past vegetation and climate history. However, to improve the application potential of these palaeoclimatological proxies in past vegetation and climate reconstructions, development of modern analogues that take into account the vegetation's composition, structure, and geographical heterogeneity is crucial. We analyze 243 modern plant specimens and 50 modern surface soil samples from various depositional settings (such as, lake bed, grasslands, open and closed forests) from two distinct forest types (dry and moist deciduous forests) from the western margin of the Bengal Basin in order to build modern reference collections that are essential to these efforts. This study aims to address whether phytoliths and stable carbon isotopes can distinguish the canopy structure and composition of dry and moist deciduous forests, and to document variations in diverse depositional environments within these forest types, if any. We observe that reference collection from modern plants is helpful to identify the plant functional types in surface soil/fossil phytolith assemblages. The results indicate that soil phytolith assemblages can reliably distinguish dry and moist deciduous forest types though, not always clearly discriminate between different depositional settings within these forest types. This incongruity may be attributed to their eolian transport, multiplicity and redundancy among the phytolith morphotypes.Though, stable carbon isotopic ratios ($\delta^{13}C$) of modern plants from the two types of forests exhibit significant differences, the values are not much distinguishable in case of the surface soils from these forests, suggesting that care should be taken when interpreting the $\delta^{13}C$ fossil records. We infer that for reliable palaeo-vegetation/climate reconstructions palaeoclimatological proxies which complement one another should be combined rather than using single proxy.

Keywords: Phytoliths, modern plants, reference collection, modern analogue, forest types, Bengal Basin

The Nesseltalgraben palaeo-lake (German Alps): Revised age model, palynostratigraphy and stable isotopes of humic acids from Marine Isotope Stage 3

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The 21 m high sediment profile at the Nesseltalgraben site (SE Germany) is currently the best dated, high-resolution lacustrine record of Marine Isotope Stage 3 (MIS 3) in the Northern Alps. A revised age model based on 30 radiocarbon dated plant remains calibrated with IntCal20 dates the record to 50-29 ka cal BP. The Laschamps paleomagnetic event was detected between 1200-1280 cm. The new age model allows the duration and timing of the Laschamps paleomagnetic event to be determined between 40.9 and 42.1 (±0.7) ka cal BP, which is consistent with previously published ages for this event.

The pollen findings indicate repeated changes from tundra to open shrub and forest vegetation. The maxima of shrub and tree pollen coincide with Greenland interstadials 5.1, 5.2, 6, 7, 8, 11, and 12, indicating a substantial increase in (summer) temperatures during these brief episodes. A massive depletion of the flora was accompanied by repeated stadial-interstadial variability, resulting in the complete disappearance of temperate genera, including several shrub and tree taxa.

Additionally, we explored the potential of humic acids for reconstructing Alpine paleoenvironment during the last glacial. Due to their formation humic acids tend to integrate environmental information over longer time periods compared to other organic proxies. In contrast to previously studied materials at the site (bulk organic matter and cellulose of bulk sediment, wood and moss), humic acids have the advantage of being available throughout almost the complete record. Hydrogen, carbon, oxygen, and nitrogen isotope records of humic acids consistently show a major anomaly at 39 ka cal BP, around Heinrich Stadial 4 (H4), and a shift to lower averages thereafter. At the same time, lithologic variability increased and coarse grained layers consistently occur suggesting a more dynamic and unstable hydrologic regime. Thus, all humic acid isotope records suggest a climatic tipping point has been reached after H4. We speculate that these changes around H4 are the result of a change in atmospheric circulation and cooling of the North Atlantic, which is also expressed by increased occurrence of permafrost around that time in Central Europe.

A high resolution multiproxy reconstruction of Late Glacial to Holocene environmental variability of tropical Lake Victoria

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The equatorial Lake Victoria (LV), Africa's largest lake, harbors a unique aquatic biodiversity of cichlid fish species that emerged after the lake's last desiccation and subsequent refilling 16,000 years ago. The origin and driving factors of this unique evolution are still not well understood. This highlights the need for a broader understanding of the linkages between paleoenvironmental variability and adaptive radiation.
We present a multi-proxy dataset of bio-geochemical indicators from four long sediment cores retrieved along a depth-transect (near-shore to offshore) in Lake Victoria. Sedimentary pigments and biogenic silica were analyzed to infer aquatic productivity. Changes in sediment composition are supported by micro X-ray Fluorescence (XRF)-derived element geochemistry, ^{13}C and ^{15}N, grain size, and sedimentary phosphorus fraction analyses. In this study, we make use of this exceptionally extensive multivariate dataset to gain a more accurate time- and space-transgressive view on environmental changes in LV. Furthermore, we determine major phases of ecosystem change by using different statistical analyses (e.g. Principal Component, Clustering and Rate-of-change analyses) and uncover their linkage to external and internal forcing factors.
The results suggest three major changes in the lake system since it's last desiccation that follow regional paleoclimate and insolation patterns: (i) the turn from a closed to an open lake system with the establishment of the Nile outflow (~13 kBP), (ii) the onset of the Holocene and the African Humid Period (AHP) (10.7 kBP) and (iii) the gradual termination of the AHP around 5 kBP. This detailed multiproxy record will help to constrain drivers of adaptive radiation and ecosystem development under changing climate boundary conditions.

Multiproxy core analysis of Holocene paleolake sediments in the Prološko Blato karst wetland (Dalmatia, Croatia)

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The Prološko Blato is a seasonally flooded karst wetland situated in the Imotsko polje in the Dalmatian hinterland, Croatia. Recent geomorphological, geophysical, and sedimentological research revealed the presence of Holocene paleolake sediments overlaying the Late Pleistocene alluvial fan deposits. Paleolake sediments were investigated by a multiproxy approach (geochemical, sedimentological, ostracod analysis), constrained by radiocarbon dating, to reconstruct paleoenvironmental evolution during the Holocene.

The paleolake sequence is comprised of three zones. The first zone is represented by the Early Holocene blackish-brown clayey silt, with a high amount of siliciclastic material (high magnetic susceptibility), high TOC, and low $CaCO_3$, and fragments of the juvenile candonid ostracods. Overall, this zone is thought to represent a time of wet and waterlogged conditions during the initial stage of the paleolake development around 9000 cal BP. The second zone marks the formation of the lacustrine environment at ca. 8000 cal BP. It is characterized by pale-colored sandy silt high in $CaCO_3$ (likely endogenic carbonate), rich macro- and microfaunal remains (gastropods, ostracods, Chara gyrogonites), and very low magnetic susceptibility. Typical lacustrine species (*Candona neglecta, Limnocythere inopinata, Darwinula stevensoni*) suggest a shallow lake environment with a well-oxygenated water column. Oxygen and carbon isotope ($\delta^{18}O$ and $\delta^{13}C$) analysis of the carbonate suggests relatively steady hydrological conditions until ca. 800 cal BP when there was a significant offset to lower isotope values suggesting wetter conditions. This offset correlates with a lithological change to Late Holocene dark brown clayey silt (third zone), characterized by higher magnetic susceptibility and TOC, and lower $CaCO_3$. The absence of typical lacustrine species in the Late Holocene suggests possible lake desiccation and the onset of the modern karst environment with seasonal flooding. Such environmental change could be related to the collapse sinkhole formation in the paleolake's marginal part, as was suggested by earlier research, as well as Late Holocene climate change.

Drowned terrestrial faunal assembalges as proxies for paleoenvironmental reconstruction of a submerged paleolandscape in central Chile (32°S).

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Late Pleistocene paleoenvironmental reconstructions in South America have used extinct fauna assemblages registered across vast areas of the continent. The site GNL Quintero 1 (GNLQ1) constitutes the first evidence of a drowned terrestrial site on the continental West Coast of South America, covered by sea-level rise after the Last Glacial Maximum. The site located in Central Chile´s coast (Quintero Bay, 32°S) currently lies 650 m offshore and 13 m.b.s.l. However, prior to the post-glacial rising of the sea level, the site was located several kilometers inland. A numerous well preserved terrestrial faunal bone assemblage was recovered, with a high taxonomic diversity, not only composed by extinct fauna Camelidae (cf. *Palaeolama* and cf. *Lama gracilis*), Cervidae, Equidae (*Equus* (*Amerhippus*) sp.) and Mylodontidae, but also by a large number of small mammals (mainly rodents) dated between ca. 29.000 to 21.500 cal BP. The results of taxonomic and geochemical bone analyses, together with isotopic and sedimentological data, allowed us to reconstruct a complex environmental scenario before the site was covered by the sea. The sequence started with the onset of a freshwater lagoon on a fluvial plain under relatively arid conditions which developed to into a wider and deeper freshwater lagoon under more humid climatic conditions, dominated by shrub and grassland, wetland and woody vegetation. Finally, the presence of dunes during the Late Pleistocene may supports the fact, that floodplains with fresh water lagoons and shallow wetlands developed among dunes, could represent a major coastal landscape for early postglacial Quintero Bay, where a high diversity of fauna was concentrated.

A new combination of automated detection and classification of Mediterranean pollen grains from annual pollen traps

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Pollen is a valuable proxy for reconstructing current and past vegetation. Automating identification and counting of pollen grains could greatly help palynologists, by increasing sample size, and thus their spatial and temporal resolutions, and standardizing methods and results. Several recent studies have already shown the potential of deep learning for automatic pollen recognition, especially for aeropalynology. Studies on pollen traps and fossil samples remain scarce, most probably because they contain many non-pollen particles and damaged pollen grains, increasing the difficulty of the task. Here, we test a new combination of last-generation deep-learning algorithms for automatic detection and classification of pollen from annual traps containing as many as 70 Mediterranean taxa, and many debris types. A total of 16 traps were collected each of three consecutive years in six locations in France. For each trap, one slide was mounted, and photographed partially with an automatic microscope. This operation produced 1,024 images of 204x204µm per slide, which contained a few pollen grains, that could be damaged, cut, or clumped, and many debris. We first trained YOLOv5 to detect the single category of pollen on 85% of 4,096 images (256 images per slide) containing 12,344 manually detected pollen grains. On the remaining 15% of the annotated images, the model left 0.7% pollen undetected, and falsely detected 12% of debris which are meant to be excluded by the subsequent classification. We then applied the model on the remaining 12,288 images and obtained 42,156 additional pollen grains. For the classification, we have trained so far ResNet50 on 85% of 8,000 manually identified pollen grains among 26 classes, made of a single or a few pollen taxa, and one extra class of debris. On the remaining 15% of the images, we obtained a class-mean accuracy of 0.73 with per-class accuracy ranging from 0.28 to 0.96. The best classification rates were obtained for taxa we had most images for (Pistacia sp., Quercus ilex, Lycopodium sp.). We are now improving the classification, e.g. by testing other algorithms, increasing the training dataset and/or through data augmentation.

New results of decadal-scale UAC measurements from a Late Holocene peat bog in NW England

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Detection of ultraviolet absorbing compounds (UACs) in Quaternary/Holocene pollen and spores has exciting potential to evaluate past changes in UV-B radiation which remain poorly known. To date, despite advances in the methods and application of UAC detection there are still very few empirical datasets on UAC changes over Holocene timescales. Therefore, new records are needed to reveal the dominant timescales of UAC changes with a view to elucidating the drivers of past UV-B variability. In this study, we performed a high-resolution analysis of UACs in pollen and spores from a Late Holocene ombrotrophic peat bog in NW England using the fourier-transform infrared (FTIR) sprectroscopy method. We undertook FTIR measurements on isolated *Sphagnum* spores and pollen grains of *Calluna* and *Alnus* for 180 samples along the core depth (2 cm resolution for 360 cm) as well as additional measurements at 1 cm resolution for the uppermost 30 cm. The core chronology is constrained by 11 AMS radiocarbon dates on either *Sphagnum* leaves and bulk peat. The sequence spans the last 3600 cal yr BP, yielding an average sampling resolution of ~20 yr (~10 yr for the last few centuries). The study interval includes several episodes of marked change in solar output (grand solar minima). We use the FTIR data on UAC abundance, supported by multiproxy datasets (core-scanning X-Ray Fluorescence, colorimetric humification, loss-on-ignition), to evaluate plant response to past UV-B variability across different taxa, with the ultimate aim of evaluating the role of solar forcing on hydrological changes in the peat bog.

Contrasted climate patterns during the Holocene in the central Mediterranean inferred from pollen data

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In the central Mediterranean region, many studies suggest that the Holocene is characterized by complex and different climatic trends on either side of latitude 40°N. This particularity in the regional climate system has been highlighted by multiple proxies showing contrasting trends of climate variations. Chironomid temperature-based reconstructions indicate the presence of a thermal optimum in Italy (10,000-7,000 cal. BP), contradicting the pollen-inferred quantification of Europe. Those discrepancies point to the need for further investigation concerning the Holocene climate of the Mediterranean region. To date, various studies have attempted to quantify the climate signal through different approaches without being able to propose a consistent climate reconstruction between proxies and sites.

In this context, and in the frame of the ANR project AUTUMNS-LAMBS, a multi-proxy method (brGDGTs and pollen) has been developed to quantify the Holocene climate in the central Mediterranean through a regional approach using multiple sites in Italy and Greece. We show here the results mainly based on pollen data, which is based on a collection of multiple sites, extracted from international pollen databases (NEOTOMA or European Pollen Database). The pollen-inferred climate is quantified by a multimethod approach, using four different methods (MAT, WAPLS, BRT and RF) and three modern databases (regional and global).

This study highlights similar climatic trends and inter-regional differences in the central Mediterranean region. Results show that not all of Europe is marked by a thermal optimum and that a longitudinal climatic gradient (40°N) in the central Mediterranean may have been present through the Holocene. In Italy, pollen and brGDGTs show a thermal optimum in the northern and central regions for the early and mid-Holocene, which is coherent with other proxies such as chironomids. This thermal optimum is less marked in southern regions of Italy, highlighting the climatic differences on either side of latitude 40°N. The late Holocene shows a climate shift between the north and the south, with a central region colder than the northern and southern ones. Moreover, the spatial heterogeneity of the Holocene climate needs to be further investigated for a better understanding of the special and temporal specificity of this climate period.

Climatic and environmental reconstruction from a primeval Fagus sylvatica forest

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Understanding climatic variability and how it affects long-term vegetation dynamics is essential to face the uncertainties of the current global change. For this purpose, we performed a paleoclimatic reconstruction for the last 2,600 cal. years BP in the Morské oko lake, located in the Inner Eastern Carpathian Mountains, Slovakia. This lake is surrounded by Fagus sylvatica forest, and the sediment, a total of 9 meters, has a high sedimentation rate, is highly organic, and depleted in oxygen content. The proxy used for the mean annual temperature reconstruction is branched glycerol dialkyl glycerol tetraethers (brGDGTs), which are membrane lipids of some soil bacteria. We also used the deuterium composition in the leave waxes to reconstruct the precipitation regime in the neighboring area for the studied period. Moreover, geochemistry data was used to assess changes in the catchment, pollen analysis to reconstruct the vegetation dynamics, and macro charcoal for the fire regime. There is considerable temperature stability in the lake and the range of the temperatures oscillates only about 2°C. The lake, which originated from a landslide, presents the greatest changes in erosion rates, climatic oscillations, and fire activity during its onset. There was a fast increase in the temperatures followed by several cooling episodes. During the last millennia, there is relatively climatic stability in contrast with the increase in fire activity. This study helps us to understand the forest dynamics and how they relate to temperature changes in this primeval beech forest in Vihorlat Mountains, proclaimed by UNESCO as a World Heritage Site.

Heinrich Stadial 4 as an emblematic arid event for the future forecasts of Mediterranean vegetation changes: inputs from a key high-resolution pollen record in the Alboran Sea

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The last glacial period (MIS5-MIS2) displayed a high climatic variability at millennial scale through the Dansgaard-Oeschger (DO) cycles and the Heinrich Stadials. Heinrich Stadials (HS) represented the most severe expression of these climate oscillations, associated to a fast spread of semi-desertic vegetation characteristic of extremely dry and cold climatic conditions in the Mediterranean area. Here, we report a high-resolution palynological record for HS 4 (~39—38.5 ka BP) from Leg 161 Site ODP 976 sequence in the Alboran sea. The results of the pollen data show a clear succession from Heinrich Stadial conditions associated with steppe taxa (*Artemisia*, *Ephedra*, Chenopodiaceae), to interstadial conditions associated with temperate Mediterranean forest (deciduous *Quercus*, Ericaceae, *Quercus ilex*). Humidity and temperature are well-evidenced as the main parameters driving vegetation changes through multivariant statistics (PCA, DCA, correlation analysis), which also clearly describe the temporal succession of samples from stadial to interstadial conditions and mimics a long-term glacial/interglacial transition. Transfer functions applied to the pollen record through a multimethod approach (MAT, WAPLS and machine-learning methods as BRT) allowed to reconstruct annual and seasonal climate parameters associated to vegetation associations through time. The results show a dramatic fall in winter precipitations and annual temperatures during the HS4. The perturbation of the typical Mediterranean regime of precipitations caused a major decrease of hydric input in the region, disfavoring water-demanding forest taxa of the temperate and Mediterranean vegetation. The return to the original regime of precipitations after the arid event allowed the recovery of the temperate and Mediterranean taxa during the DO8. These results are in line with previous studies on the last deglaciation from the same core sequence, showing the high sensitivity of Mediterranean ecosystems to climate variability and especially hydric stress during the last 40 ky BP. In conclusion, future high-resolution studies of paleoenvironmental changes at millennial scale such as Heinrich Stadials, associated to climate modelling methods, might bring new data of high precision to assess human societies resilience to climate variability along the last glacial period.

Central Italy through the Early Pleistocene: Floristic dynamics in a chronostratigraphic framework

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Palynological records are a powerful tool for reconstructing past distribution dynamics of plant groups, and a supplement to the regional chronostratigraphic framework documented by other datasets (e.g., δ^{18}O and magnetostratigraphic data). There have been numbers of palynological studies carried out in the Lower Pleistocene of central Italy; however, most of them are without age constraints. Here we aim at setting a framework of the distribution patterns of major taxa in the Early Pleistocene of central Italy, by comparing previously investigated, but chronologically poorly constrained, pollen records (i.e., at Gubbio, Leonessa, Madonna della Strada, and Pagliare di Sassa) with a relatively well-dated, recently acquired record from the Castelnuovo 1 borehole, in the L'Aquila Basin, central Italy, spanning the 2.1-1.5 Ma interval. The Castelnuovo palynoflora contains more than 100 sporomorphs, belonging to vegetation types of subtropical humid forest (including sporadic *Taxodium* and *Cathaya*), mixed temperate forest (including *Acer*, *Alnus*, *Quercus*, *Carya*, and *Liquidambar*), Mediterranean sclerophyllous forest (including *Quercus ilex*, *Olea*, *Phillyrea*, and *Pistacia*), steppes (including Amaranthaceae, *Artemisia*, and *Ephedra*) and other open vegetation (including Asteraceae, Cyperaceae, and Poaceae). The comparison between Castelnuovo and the other four above-mentioned palynofloras suggests that temperate and high-altitudinal taxa (including *Tsuga*, *Carya*, *Pterocarya*, *Cedrus*, *Picea*, *Abies*, *Quercus*, *Carpinus* and *Fagus*) were common in the Early Pleistocene of central Italy, while some taxa (including *Liquidambar*, *Cathaya* and *Taxodium*) occurred occasionally, and *Engelhardia* and *Sciadopitys* disappeared. As within a chronostratigraphic framework, the Castelnuovo succession will provide an excellent example for future palynological correlations (e.g., the ongoing Avezzano project with multi-proxies) in central Italy. Furthermore, this study will shed further lights on how the Early Pleistocene climatic oscillations (glacial-interglacial cycles) determined the distribution and extirpation of plants and thus vegetation patterns in central Italy.

Mid-Holocene human-environment dynamics in Italy inferred from the Botanical Records of Archaeobotany Italian Network (BRAIN)

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The current biodiversity loss involves complex scenarios with impacts on climate and economy and challenging health and social implications. The study of environmental transformations in a long-term perspective is the high road to biodiversity protection and understanding the risks and resilience of ecosystems. The diachronic study of global changes and the rapid development of big data in this field ensure a rapid increase in knowledge to guide nature conservation policies.

This paper focuses on the study of human-environment dynamics in Italy over the past 6,000 years based on data on plant biodiversity of natural (off-site: lake basins or peat bogs) and anthropogenic (on-site: archaeological sites) origin provided by Botanical Records of Archaeobotany Italian Network and database. The BRAIN web site (https://brainplants.successoterra.net/index.html) hosts the inventory of the archaeological researches including pollen, palynomorphs, seeds/fruits, wood, charcoals and other plant remains analyses from hundreds of sites in Italy and the Mediterranean. Case studies of pollen records providing information on environment dynamics in different Italian regions have been selected to put on evidence local features of land use and transformation.

The BRAIN datasets processing highlights the composition and changes in vegetation cover, recorded at regional and local scale, under climate and human impacts. Since ancient times, the Italian landscape has always been subject to continuous transformations in response to climate-environmental changes, tuned by cultural forcings such as agriculture and other anthropogenic impacts.

The phytolith record of Lake Ngami, Botswana, during the past 16 ka and correlation with other paleoclimatic and palaeoecological proxies

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Lake Ngami occupies the southwestern part of the rift that forms the southern overflow catchment of the Okavango Delta. Past studies on paleo-landforms around the lake and paleoecological proxies from the lake suggest extreme changes in prehistoric and historic times. The previously published pollen record provides the pattern of regional and local vegetation change in relation to climatic and hydrological fluctuations, suggesting changes in precipitation patterns related to regional circulation patterns. The more recent phytolith record provides additional information that although concurrent with the pollen record provides additional information regarding responses of grasses to regional and local climatic and hydrological changes. Based on phytolith assemblages in modern depositional analogs across a broader area suggest that the well-defined round saddle, produced by the arid-adapted *Stipagrostis* spp (bushman grass) is a good indicator of aridity. The role of short cells produced by the Chloridoideae and Panicoideae suggests different moisture regimes. This contrasts with the idea that Chloridoideae are indicative of dryness. Likewise, the presence of woody-plant phytoliths relates more to the reduction of lake level and spreading of deep-rooted thorn trees on the lake floor. The study is a contribution to interpreting phytolith assemblages in shallow lakes in the tropics of southern Africa.

Underwater Old-growthTrees and the Past Millennia of Climate and Forest Dynamics in Eastern Canada

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Old-growth forests are important natural archives of past environmental conditions. In the forests of eastern North America, eastern white cedar (*Thuja occidentalis*) is late-successional species known in the region for its record-breaking lifespan. Before the industrial period, old-growth cedar forests dominated lakeside ecosystems, but extensive commercial logging has profoundly altered the role of this species in the landscape. The few old cedar forests that remain are important relics of prehistoric information. Lakeshore cedar trees that have fallen into the water are preserved for centuries after their death in the low-oxygen environment of lakebeds, creating an opportunity to infer a millennia of environmental history. Dating the ring widths of lakeshore cedars, above and below the shoreline and studying the patterns of growth, death and deposition among them reveals important insights into the dynamics of these relic forests and their connection to past climate. The cedar trees of this region show a significant relationship to seasonal river flow records, allowing for a reconstruction of moisture conditions over the past millennia. Insights from relic old-growth cedar forests improve our understanding of climate variability and long-term forest dynamics in eastern Canada.

Middle to Late Pleistocene alluvial paleosols in eastern Sudan as indicators of palaeoclimate

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The Atbara River in eastern Sudan is the last major tributary of the Nile before it flows through the Sahara. Along its middle reach, Pleistocene alluvial sediments, dated to about ~ 250 to ~ 15 ka, are exposed for about 200 km with a maximum thickness of 50 m. The Pleistocene sediments are rich in vertebrates and stone tools. Previous work identified two sedimentary units separated by a major unconformity, the Butana Bridge Synthem (BBS) and the Khashm El Girba Synthem (KGS), each subdivided into three intervals BBS 1-3 and KGS 1-3, from bottom to top. The BBS 2-3 and KGS 1-3 contain paleosols characterized by pedogenic features. Additionally, the BBS 2-3, KGS 1 and KGS 3 paleosols formed during MIS7, MIS6 and MIS2, whereas the KGS2 paleosols formed during MIS5 and MIS4. We used the paleosols to reconstruct the paleoclimate in the study area by performing mineralogical, petrographic, geochemical and isotopic analyses.

The field studies and the laboratory results indicate that paleo-Aridisols and paleo-Vertisols are most common, which are soils typical of arid to semi-arid and seasonally moist to subhumid climates, respectively. The Aridisols are common in BBS 2-3, KGS 1 and KGS 3. They are characterized by calcretes and contain carbonate, sulfate and halide minerals. Clay minerals are dominantly smectite and chlorite; easily weatherable silicate minerals (e.g. feldspar) and mica are also common. Vertisols that exhibit blocky peds and pedogenic slickensides are dominant in KGS 2 paleosols. Chemical index of alteration (CIA) values suggest that both paleosol types underwent moderately intense weathering during their formation. Mean annual precipitation (MAP) proxies show no significant variation between paleosol types, with an average of 818 ± 182 mm yr^{-1}, which is higher than the present-day precipitation. Minerals such as zeolite, hornblende and chlorite in both paleosol types point partially to mafic source rocks such as basalt, which are widespread in the modern Atbara drainage basin. The $\delta^{13}C$ isotope values of calcretes indicate that the vegetation varied between grassland, wooded grassland and woodland / bushland / thicket / shrubland.

Keywords: Middle Atbara, calcrete, paleosols, Aridisols, Vertisols

Tephrochronology of marine sequences in a cold seep area of the SE Tyrrhenian Sea (Paola Basin) as a tool to reconstruct main episodes of methane release

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The occurrence of hydrocarbons seeping in the marine environment is frequently overlooked due to the paucity of ocean exploration data. Reconstructing past and present hydrocarbon dynamics is not only crucial in polar regions, where bottom water warming may lead to gas hydrate destabilization, but also in other areas of the world where free gas in the sediment might be released to the seafloor, the water column and potentially to the atmosphere.

Understanding the timing of methane release is not always straightforward but can be achieved using specific and combined proxies left in the geological record.

In this study, we present the first attempt to correlate tephra deposits among marine sediment cores collected in cold seeps of the southeastern Tyrrhenian margin (Paola Basin). Sediment cores contain methane-derived authigenic carbonates that precipitated due to Anaerobic Oxidation of Methane in the Sulfate Reduction Zone with associated chemoautotrophic symbiontic shelly mega fauna. The down-core trend of abundance and isotopic characteristics of clam beds, benthic and planktonic foraminifera showed that these seep sites have remained geochemically optimal habitats over a period of more than 40,000 years. Episodes of enhanced methane flux were tentatively dated using radiocarbon on macro fauna shells and foraminifera.

In the sediment cores, tephras occur as both primary and secondary deposits and were recognized and correlated through visual inspection, magnetic susceptibility, core-scanner X-Ray Fluorescence using diagnostic elements and element ratios. Electron microprobe and LA-ICP-MS analyses were carried out on single glasses of selected primary tephra in order to characterize their composition in terms of both major- and trace-element content.

The composition of the tephras indicate provenance from the volcanic provinces of Aeolian Islands, Campi Flegrei-Vesuvius, Pantelleria. In particular, correspondence was found for basaltic trachy-andesite to trachy-andesites samples with the Intermediate Brown Tuffs units (Aeolian Islands), for the almost trachytic samples with the Campanian Ignimbrite (Campi Flegrei) and for rhyolitic to trachytic samples with the Pantelleria Green Tuff.

This multi-proxy approach provided a valid tool to constrain the chronology of the main episodes of methane release and at the same time allowed to augment previous tephra studies of the region.

Windblown diatoms in the Roosevelt Island ice core: a proxy for local paleo-environmental changes

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Both marine and freshwater diatoms are commonly found in polar ice as a result of aeolian transport, and the identification of their species is essential to shed light on their source environment and transport pathways. In Antarctica, while pioneering studies on windblown diatoms were principally devoted to the resolution of the "Sirius debate", many studies recently aimed at using diatoms as tracers for air mass paleo-circulation. As an example, glacial ice from central East Antarctica (Dome B) revealed enhanced transport from the exposed continental shelf of Argentina and glacial-outwash sediments of Patagonia at the time when sea level reached its minimum. For recent climate, the potential of diatoms as proxy for wind strength over the Amundsen and Bellingshausen Seas has been demonstrated from annually-resolved firn cores from the Antarctic Peninsula.

In this work we investigate windblown eolian diatom valves archived in the RICE ice core, drilled onto the Roosevelt Island ice rise in West Antarctica, and use this proxy as indicator for local paleo-environmental changes at the site.

The record covers the last 12 kyr and the diatom assemblage is clearly dominated by *Fragilariopsis* spp., a marine diatom genus that includes planktonic, a few benthic and some ice-associated species. Optical microscope imaging and sizing of microfossils extracted from the RICE ice samples allows attributing about 75% of the diatom valves assemblage to *F. nana* and about 25% to *F. cylindrus* and/or *F. curta* according to morphometric data of *Fragilariopsis* spp. reported for the Antarctic seas. All these species have been mostly documented in the Southern Ocean cold water region, both in plankton and sea ice.

Over the last ca. 2700 years, the diatom concentration shows a sudden increase during the "Little Ice Age" and in particular in the 16th and 18th centuries, at the time when snow accumulation and dust influx decrease, while the stable isotope composition of the ice shows a small increase. One possible explanation for this sharp diatom concentration rise could be the development of a Roosevelt Island polynya, although additional, complementary data are needed to validate this scenario.

Deciphering eastern African environmental extremes and hydrological threshold conditions during the last 620,000 years: authigenic minerals in the Chew Bahir record

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The ~620,000-year-long climate record from Chew Bahir in southern Ethiopia documents the potential influence of different episodes of climatic variability on hominin biological and cultural transformation and presents therewith an unparalleled opportunity to better understand the environmental context of human-climate interactions during the Pleistocene. The coring locality of the 280-m long cores of sedimentary strata is situated near key archaeological and paleoanthropological sites, such as the Omo-Kibish where the Omo 1 and 2 *Homo sapiens* fossils were recovered. The effect, timing and especially the extent of environmental extremes and hydrological threshold conditions in one of the habitats of hominin populations is however not well understood yet. The key question in this context is: how dry was dry?

The Chew Bahir mineralogical record that provides the opportunity to decipher environmental extremes and hydrological threshold conditions. The degree of authigenic mineral alteration is indicative of wet, dry and especially hyper-arid climate intervals. Our results show that the most extreme evaporative phases are represented by authigenic mineral assemblages including Mg-enriched clays, low-temperature authigenic illite and euhedral analcime. Linking the mineralogical profile (XRD) with geochemistry (µXRF) and isotope geochemistry ($\delta^{18}O_{calcite}$) enables us to more finely differentiate levels of aridity, define depositional conditions and environmental thresholds through time. The oscillations between pronounced hydroclimatic conditions have important implications for transforming the habitats of human populations The time interval described by the core data encompasses several key hominin evolutionary benchmarks, including the transition to the Middle Stone Age, and the origin and dispersal of modern *Homo sapiens*.

A Bayesian Hierarchical Time Series Model for Reconstructing Hydroclimate from Multiple Proxies

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The Australian continent experiences hydroclimatic variability that is regarded as extreme compared to the rest of the world. Hydroclimatic risk in Australia is typically assessed using instrumental records of rain, evaporation, and streamflow that have existed for about the last 100 years, at best. Palaeoclimate proxy records provide indirect estimates of past local or regional hydroclimate and, with the use of appropriate statistical techniques, offer the scientific community an opportunity to extend instrumental records back in time and better elucidate natural climate variability. To that end, we present a Bayesian model which produces probabilistic reconstructions of hydroclimatic variability in Queensland Australia, using instrumental records of hydroclimate indices such as rain and evaporation, as well as palaeoclimate proxy records derived from natural archives such as sediment cores, speleothems, ice cores and tree rings. The method provides a standardised approach to using multiple palaeoclimate proxy records for hydroclimate reconstruction. The approach combines time-series modelling with inverse prediction to quantify the relationships between the hydroclimate and proxies over the instrumental period and subsequently reconstruct the hydroclimate back through time. We present model-based reconstructions of the Rainfall Index (RFI) and Standardised Precipitation-Evapotranspiration Index (SPEI) for two case study catchment areas, namely Brisbane and Fitzroy. In Brisbane, we found that the RFI is unlikely (probability between 0 and 20%) to have exhibited extremes beyond the minimum/maximum of what has been observed in the instrumental time period between 1889 and 2017. However, in Fitzroy there are several years during the reconstruction period where the RFI is likely (>50% probability) to have exhibited behaviour beyond the minimum/maximum of what has been observed. For SPEI, the probability of observing such extremes prior to the end of the instrumental period in 1889 doesn't exceed 50% in any reconstruction year in the Brisbane or Fitzroy catchments. Such information from catchment-scale hydroclimate reconstructions helps us to improve our understanding of the longer-term context within which known historical (i.e., instrumental) hydroclimate exists and can provide a point of comparison for future projections.

Using sedimentary ancient DNA of aquatic macrophytes to reconstruct postglacial freshwater environments

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Environmental DNA is increasingly used to reconstruct past and present biodiversity including from freshwater systems. Here, we investigate the extent to which sedimentary ancient DNA records can be leveraged for reconstructing local environmental conditions, using a case study based on aquatic macrophyte ecological niches. We used a metabarcoding dataset from ten lakes in northern Fennoscandia, mapped to a near-exhaustive reference barcode library (PhyloNorway); which we combined with a database of biotic and environmental traits of the Swedish flora. We reconstructed thermal range, continentality, water pH, trophic status, and light conditions in northern Fennoscandia freshwater ecosystems throughout the Holocene. The earliest record, comprising only 3 lakes for the Late Pleistocene, is characterised by mild conditions and habitat complexity. Individual lakes showed differing trends, with locally high variability of climatic and physico-chemical conditions. However, most lakes did not exhibit much fluctuation in trait composition during the last 9,000 years, resulting in an overall stability on the regional scale. Combined with the availability of near-complete barcode and traits databases, metabarcoding data can support wider ecological reconstructions that are not limited to aquatic plant taxonomic inventories but are also used to infer past environmental changes ranging from water-quality to climate. Sedimentary ancient DNA is shown to be a powerful tool to infer past environmental conditions from ecologically and climatically indicative taxa.

Does hydroclimate drive mercury fluxes in Lake Bosumtwi, Ghana?

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Mercury (Hg) is a volatile metal released into the atmosphere by both natural processes and human activity. The rate of transport, deposition and revolatilization of Hg in the terrestrial environment is driven by processes intimately coupled to climate, and which operate on pre-industrial timescales. Research has shown substantial Hg accumulation in tropical ocean sediments. Observed signals have been linked to changes in trans-continental precipitation patterns, tropical rain belt migration, and/or rates of sediment delivery to the ocean by run off – all as a function of climate-driven shifts in moisture availability on both short ($<10^1$-year) and long ($>10^1$-year) timescales. However, it is unclear whether these processes also impact lacustrine Hg fluxes. Previous studies have attributed the magnitude and expression of lacustrine Hg fluxes both to lake-specific processes such as sediment diagenesis and water balance, and also to catchment characteristics including ecosystem structure, surface hydrology, dust flux, and human activity. High-resolution, continuous sediment records of Hg cycling in the tropics are required to resolve the relative importance of these processes over decadal-to-millennial timescales. We present a record of Hg accumulation and deposition in Lake Bosumtwi (Ghana) between ~100–0 ka. Lake Bosumtwi is a closed, meromictic lake occupying a 1.08 ± 0.04 Ma meteorite impact crater and provides a continuous record of climate and environmental change in West Africa since ~100 ka. New Hg measurements reveal a coupled response between Hg flux and shifts in sediment lithology and composition indicative of changing lake level. We find that the amplitude and frequency of peaks in Hg increases as lake level rises, and decreases as the lake level falls. Together, these observations allude to a link between Hg flux, lake water balance, and regional moisture availability. By synthesizing our results with evidence obtained from the Bosumtwi system and the wider West African region, we can better understand the drivers of the changes in Hg deposition, and assess how these signals relate to centennial-to-millennial-scale changes in tropical vegetation, hydrology, and land use.

Session 102: West African Quaternary: understanding past climate oscillations and human responses to anticipate future adaptations

Environment, culture and African Thought

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The emergence of man in Africa as well as in the whole world revolutionized the environment in which they lived and still living. Conscious of the dictate of their environment, African man adjusted, related and adapted to the dictate of the environment.

The survival dictate led them to the manipulation of the environment and subsequently changed and continuing changing the environment and leading to climatic changes.

In this paper, the thoughts of the African man were examined on their traditional ways of protecting the environment and how these thoughts are being denigrated as a result of the influence of other people's culture, tradition and religion.

It concludes that serious action should be taken to protect these thoughts, adapt and modify according to the dictate of the present situation.

Sedimentologic and palynological appraisal of lithostratigraphic sequences of the eastern fringe of Dahomey Basin, Nigeria. West Africa

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Integrative studies were carried out on fifty (50) ditch samples retrieved from drilled wells within the sedimentary sequences within Lagos. Lithologic study was carried out on the ditch samples which were logged at five (5) meter intervals and their litho-profiles were generated. Thin section petrography was done to determine diverse lithofacies constituting the sediment. The heavy mineral analysis is to evaluate the constituted mineral assemblages as well as the provenance of the sequences. The palynological study was carried out to evaluate the palaeoclimate, ages, palaeoenvironment and biozonation of the recovered palynomorphs. The lithologies of the studied wells (Ikorodu (IK) and Lekki (LK) wells) comprised of clayey sands, silt, clay, peat, granules and detrital fragments. The petrography revealed that the lithofacies were reworked sediment sourced from igneous and metamorphic sources hence suggested to have been transported by river. The wells have sandstone of > 90% quartz with the inclusion of other minerals constituting 10%. This suggests supermature sediments that have experienced medium transportation history in both wet and dry climates. This is corroborated by the heavy mineral assemblages that revealed the presence of zircon (Z), tourmaline (T), rutile (R), garnet (G), apatite (A), hornblende (H) and sillimanite (S), all indicating mature sediment. The palynology revealed a total of one hundred and thirty-two (132) palynomorphs. Three palynozones identified are characterized by the occurrence of *Avicennia africana, Drepanocarpus lunatus, Leiosphaeridia* sp., *Alchornea* sp., *Elaeis guineensis, Cassia* sp., *Psychotria* sp.; *Elaeis guineensis,* and *Protea* sp. The palaeoenvironment of deposition varies from marine to freshwater, while the presence of *Zonocostite ramonae* form suggests mangrove swamp forest (IK well). Based on the recovered palynomorphs, the lithofacies are dated Oligocene to Recent.

Keywords: Palynology, biozones, lithofacies, palaeoenvironment, assemblages.

Reconstitution of the paleoenvironments of the Venvé swamp in northwestern Benin : a palynological study.

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Detailed analysis of a core sample (2 m long) taken from a marsh located in Copargo (Djougou) allowed us to reconstruct the environment from the beginning of its formation to the present day. Field sampling was carried out using a Martin vibratory corer (Martin and Flexor, 1989), which allows an aluminum tube to be driven into the ground on a tripod. Sediment samples from the core were processed using the method of Faegri and Iversen (1989). Lithologic diagram construction was performed using the Munsell Soil Color Charts (2009). Pollen enumeration and identification was used to construct pollen diagrams and reconstruct the vegetation history around the site. The sporopollen study is complemented by the stratigraphic analysis of organic sequences and the floristic inventory. However, the chronostratigraphic framework remains undetermined. The results obtained allow 1) to understand the sedimentary dynamics of the marsh and its gradual transformation into a peat bog, 2) to verify the correspondence between the fossil pollens and the current vegetation of the marsh. It was found that the ancient vegetation did not undergo a profound change compared to the one found on the site today. Indeed, pollens of forest species such as Trichilia type, Diospyros type, Entada type, Terminalia type, Bombax sp, Newbouldia laevis were observed during the pollen analysis. Their presence gives an indication of the type of climate that would have existed at that time as well as the type of plant formation. The pollen data showed that site was occupied by a dense semi-deciduous forest type of plant formation and that the climate would be warmer and wetter in this area, which normally has a drier Sudanian climate. Indeed, semi-deciduous dense forests are found further south with a Guinean or Sudano-Guinean climate. The Venvé swamp belongs to a gallery forest where conditions were more humid. This has favored the maintenance of the dense semi-deciduous forest in this part of the Sudanian zone. Vegetation dynamics existed during the Quaternary on the banks of the Venvé Marsh. Further climate and dating studies would provide more information on the establishment of this vegetation type in the Sudanian zone.

Variable correlation between the West African Monsoon and global indices during the Last Millennium

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West Africa has experienced pronounced interannual to multidecadal rainfall variability during the 20th century, resulting in devastating periods of drought and famine in the region. This is generally thought to be associated with global climate SST variability indices such as the Atlantic Multidecadal Variability, the Atlantic Niño and the El Niño Southern Oscillation. However, while these variability patterns are not stationary, and some studies have indicated a shifting relationship between the monsoon rainfall and the SST indices during the 20th century, how these relationships change on a multidecadal to centennial scale is not well understood due in part to the limited availability of long observational datasets and low paleoclimate proxy coverage in the region. Climate model simulations of the 'last millennium' (850-1850 CE) may provide opportunities to examine such temporal and spatial variability in the relationships. Increasing our knowledge on how these relationships have varied in the past will also help inform on the impact on the West African Monsoon by future spatial and temporal changes to different SST variability patterns. Here, we analyse model output from a 'last millennium' simulation produced using the fully coupled ocean-atmosphere-land model EC-Earth 3. The model results show a clear centennial variability in the correlation between the West African Monsoon and the Atlantic Multidecadal Variability, the Atlantic Niño and the El Niño Southern Oscillation through the last millennium. The varying correlation is linked to changes in the spatial pattern of the SST indices, which modifies how they impact the West African Monsoon and its regional rainfall.

Past climate reconstruction: Inherited month's names as a cultural model in the Kingdom of Dahomey in Benin (West Africa)

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The lack of statistical or instrumental data lead to use historical archives and cultural models' heritage to understand paleo-climatic mutations and reconstruct past climates. This study aims to characterize the climate evolution using historical archives and the months referred to climatic and agroclimatic events in the Kingdom of Dahomey (southern Benin), established around the year 1600 by the Fon people.

The study is based on analysis of historical archives, decryption of the inherited months names and recorded climate data. Compiled data help to reconstruct the paleoclimate and its recent evolution focusing on criteria as average monthly rains (Rm) and temperature (Tm) and seasonal (Rs and Ts), recorded at the station of Bohicon over 1940-2021.

The inherited month names and change of some agroclimatic events show an evolution of the ancient to recent climate. Thus, January (*alunsun*), drought month (Rm = 6.9 mm; Tm = 28.7 °C); March (*xwejisun*), month of the yearly first rain (Rm = 82.8 mm; Tm = 29.9 °C); August (*avuvosun*), cold month (Rm = 96.3 mm; Tm = 25.6 °C); December (*woosun*), harmattan month (Rm = 12.7 mm; Tm = 28.6 °C) still observable testify to the recent stationarity of the subequatorial paleoclimate. But, the cultivation of pearl millet (*Pennisetum typhoides*), a crop in the Sahelian and Sudanian climates (Rs between 200 to 700 mm and Ts = 28 °C) was done by its planting in April (*lidosun*) and its harvesting in July (*liyasun*). The current seasonal rain for the growth stages of pearl millet (60 to 90 days), no longer significantly cultivated (replaced by maize), varies from 282.1 to 1110.00 mm (Ts = 27.5 °C) with 13 % of unfavorable years. The disappearance of pearl millet cultivation reveals that the tropical paleoclimate (semi-arid) would have evolved into an unfavorable subequatorial climate (humid) on the Kingdom of Dahomey.

The climate effects on people and their innovative adaptation capacity helps to preserve the memory of paleoclimate and its variation in the absence of instrumental data.

Keywords: Kingdom of Dahomey, inherited month name, recorded data, paleoclimate memory, Benin.

Reconstructing paleoclimate and paleoenvironment using lipid biomarkers in Western Central Africa: the NGaoundaba peat deposit (Cameroon)

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Since the beginning of Holocene (last 11ka), African climate has encountered large paleoclimatic and paleoenvironmental changes from a globally wet climate at the beginning of the Holocene also known as the African Humid Period to a drier period from 5/6 ka to present days. Recent dry climate is not favorable for sediment deposition and preservation leading to rare and often uncontinuous records complicating paleoclimatic and paleoenvironmental interpretations based on sedimentary archives. In this study, we investigate a continuous and homogeneous 6-meter peat core from the NGaoundaba peatland (Northeastern Cameroon) over the last 10ka using a large panel of lipid biomarkers of various biological origins [microbial isoprenoid and branched glycerol-dialkyl-glycerol-tetraethers (isoGDGT and brGDGT respectively), higher plants *n*-alkanes, bacterial hopanoids and degradation products of plants]. Using variations in abundance, concentration, isotopic composition of lipids or recently developed peat-specific organic proxies, we reconstruct past changes in vegetation, precipitation, temperature or methane cycle to better understand the timing and pattern of the African Humid Period both locally and at a regional scale by comparing with other records.

A diverse assemblage of lipid biomarkers was detected: C_{17} to C_{37} *n*-alkanes, C_{27} to C_{31} hopanes and hopenes, both regular and H-shaped brGDGTs and isoGDGTs, among others. From 10 to 6ka, brGDGT-based reconstructed temperature and $\delta D_{C31\ n\text{-alk}}$ indicate warmer and wetter climate compared to present conditions, coinciding with the African Humid Period. From 7.9 to 8.9ka, depleted values of $\delta D_{C23\ n\text{-alk}}$ and high abundance of biomarkers usually associated with freshwater lake and microbial organic matter suggest a period of development of the peatland with an increase in-situ production. Abundance of *n*-alkanes and degradation products of plants and $\delta^{13}C_{n\text{-alk}}$ indicate a higher proportion of C3 plants from 8 to 6ka during the African Humid Period compared to present day where C4 plants are more frequent.

Study of the Recent Quaternary of the Southwest Coast Benin, from archaeological and archaeobotanical Data: results and perspective research

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The Quaternary is marked by alternating cold, long glacial phases and warm, shorter interglacial phases according to climate reconstruction models. These different phases led to changes at different levels on the globe as in West Africa. Indeed, it has been noted that these changes do not cover the same importance. Thus, a phytogeographic break called Dahomey-Gap observed between Nigeria and Ghana while the rest of the coast is covered with dense semipivirous forests has been noted. Could this phytogeographic anomaly be due to climatic causes or anthropic actions? Indeed, this break in the two forest blocks raises many questions about the relationship between vegetation and human activities over the past millennia. Research projects have already been conducted to study this phenomenon in Benin, but they do not cover all areas of this phytogeographic anomaly. It is therefore in search of explanations to this phenomenon that the QuaReB research project was born and proposes to collect data on the fishing route in southern Benin. The paper entitled ¨Etude du Quaternaire Récent de la Côte Sud du Bénin, à partir de données archéologiques et botaniques¨ (Study of the Recent Quaternary of the South Coast of Benin, based on archaeological and botanical data) will present the results obtained and the research perspectives by the QuaReB project team at the XXIst Congress of the International Union of Quaternary Sciences.

Session 103: Terrestrial hydroclimates: towards quantification and climate model comparisons

Exploring the causes of a multicentury pluvial event in the Altiplano with an idealised modelling experiment

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Rainfall in the Altiplano is scarce and largely limited to the austral summer months (DJF), representing a critical hydrological resource for several million of people in South America. From interannual to decadal timescales, summertime rainfall variability in the Altiplano results from a complex interplay between upper and lower-tropospheric features, which is ultimately modulated by equatorial Pacific SSTs (i.e., El Niño Southern Oscillation, ENSO) and Atlantic cross-equatorial thermal gradients. However, drivers of long-term changes (100+ yr) are still largely unknown, which limits our understanding of natural and anthropogenic-caused anomalies and the capability of models to project future trends.

The combination of detailed paleoclimate series and climate simulations capable of capturing regional and local scale features is a novel approach to explore long-term hydroclimatic trends and drivers. Recent paleoclimate reconstructions from Altiplano showed what seems to be a ~400 yr pluvial event that occurred ~2000 yr ago. Yet, this event is hardly observed in records from tropical South America further north, which led to propose an intrusion of extra-tropical moisture as a potential cause. To decipher the mechanisms of multicentury pluvial events in the Altiplano we performed an idealised modelling experiment using the Weather Research and Forecast Model (WRF), a regional climate model. We simulate long-term rainfall responses forced by two different configurations that enhanced summertime precipitation in recent historical times. Preliminary results from our experiment shows that neither cold equatorial Pacific SSTs nor warmer south tropical Atlantic temperatures are capable of sustaining long-term positive summer precipitation anomalies.

Our simulations further suggest that Warm SSTs over the coast of southern Brazil and Argentina may have not driven the occurrence of multicentury pluvial events as observed in paleoclimate records. Similarly, persistent cold conditions in the Pacific are unable to simulate century-long humid anomalies, although we did not force our simulations with strong La-Niña conditions. Our experiment provides a novel approach to explore the causes and mechanisms of long-term hydroclimatic change in the Altiplano.

Water cycle and vegetation influences on leaf-wax δD variations: a modelling approach

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The hydrogen isotopic composition of leaf wax, i.e. δD_{wax}, is derived from long-chain n-alkane that are abundant in the leaf of higher plants and well preserved in the sediments over millions of years. This proxy is usually used to infer indirect changes in the local water cycle, even if its quantitative interpretation is still an open question. The δD_{wax} signal is complex to interpret since it depends on the climate (precipitation, relative humidity, temperature), the vegetation and several isotopic fractionation processes. Additional constraints are then needed to decipher the influence of the drivers on the δD_{wax}.

We present here the first modelling approach of the δD_{wax} in a coupled climate model. The intermediate complexity model iLOVECLIM is used to develop a new module to simulate the hydrogen isotopic composition of the leaf wax, including the variation of the water isotopes, the distribution of the vegetation with 26 plant types and the isotopic fractionation processes associated with the evapotranspiration and the biosynthesis of the leaf wax. The results obtained for the Preindustrial show that the δD_{wax} presents similar spatial variations than the hydrogen isotopic composition of precipitation. The isotopic fractionation associated with the biosynthesis of leaf wax also appears to be a major driver of the δD_{wax} variations. To obtain a good model-data agreement, it is necessary to account for the role of the vegetation and of the plant types diversity on the isotopic fractionation values. This modelling approach highlights the key role of the vegetation, in addition to the water cycle, on the δD_{wax} variations.

Quantitative paleo-humidity reconstructions during the Iberian Roman period from stable isotopes of gypsum hydration water

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Quantitative paleoclimate records are scarce, yet important for validation of climate change models. Here we quantify changes in atmospheric relative humidity (RH) in the southern Iberian Peninsula from 3.3 to 1.4 cal ky BP, spanning the time of the Roman domain of Iberia. We reconstruct the triple oxygen (δ17O and δ18O) and hydrogen (δ2H) isotope composition of paleo-lake water in Laguna Grande de Archidona (Málaga Province) from the stable isotopes of the structurally-bonded gypsum hydration water. An evaporation isotope-mass-balance model is used to determine the range of hydro-climatic conditions that satisfy the isotopic composition of the paleo-lake water. We validate our approach by analyzing sub-actual gypsum (1997 to 2018 CE) and found that the results are consistent with lake water evaporation under RH of 54±1%, similar to the modern RH during the dry season. The sedimentary record shows that a shift from drier to wetter conditions occurred from 2.59 to 2.37 cal ky BP, when RH increases by ~8% (from 53±3% to 61±3%). Subsequently, a gradual decrease in RH extended from 2.31 to 1.43 cal ky BP and RH was 56±3‰ at 1.43 cal ky BP. The driest episodes occurred at 2.58, 2.22 and 1.52 cal ky BP, when RH fell below 54%. These arid stages match with positive phases of the North Atlantic Oscillation. Our results suggest that the hydro-climate in the southern Iberian Peninsula during Roman times was controlled by changes in regional atmospheric patterns.

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Millennial-timescale quantitative estimates of climate dynamics in central Europe from earthworm calcite granules in loess deposits

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Over the last glacial period, the climate of the Northern Hemisphere experienced numerous abrupt variations on millennial to centennial timescales known as Dansgaard-Oeschger events. Their understanding is underpinned by the Greenland ice core and North Atlantic marine records; terrestrial responses and potential feedbacks are less well documented. Loess-palaeosol sequences in central Europe often record these climatic changes in the form of brown soils and tundra gley horizons - indicating milder interstadial conditions - intercalated with primary loess deposits reflecting cold stadial conditions.

Here we make use of a singular material for quantitative, high resolution palaeoclimate reconstruction from loess sediments: fossil earthworm calcite granules (ECG). ECG are secreted daily at the soil surface mostly by *Lumbricus* species and experience limited vertical mixing within the loess sedimentary column. Our terrestrial data derive from stable isotopic geochemistry and radiocarbon dating of ECG, collected from two temporally overlapping loess-palaeosol sequences: Schwalbenberg and Nussloch. These sequences are located c. 180 km from one another along a NNW-SSE transect in the Rhine River valley of western Germany, archiving regional terrestrial responses to the oscillating climate of the period ~ 45-22 cal kBP (late MIS 3 - MIS 2). We present warm-season land-surface temperature and precipitation estimates at millennial timescales.

Over the time interval studied, we demonstrate that MIS 3-2 climate in the Rhine Valley was significantly cooler during the warm season and overall drier with annual precipitation reduced by up to 70%, compared to the present day. Interstadial conditions were only slightly warmer (1-4°C) than stadial ones - a difference which appears strongly attenuated compared to Greenland records. We combine quantitative estimates with mesoscale wind and moisture transport modelling, demonstrating that this region was dominated by westerlies and thereby inextricably linked to North Atlantic climate forcing.

Our approach represents a useful combination of high-resolution age-depth modelling and geochemical proxy-based climate reconstruction which can be readily adopted at other loess palaeosol sequences. A widespread application of this approach would provide an improved understanding of the regional variability over the European continent in response to North Atlantic climate changes over millennial to centennial timescales.

The effects of the temperature increase on the rainfall regime in north-central Italy

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In the last years, several works analyzed climate databases and applied physical models to study rainfall regime changes in Europe and in the Mediterranean, specifically identifying a different behavior in the rainfall regimes between northern Europe and the Mediterranean regions over the last years. This seems to indicate the presence of climatic transitional zones, like north-central Italy, where there is the passage from the wet areas of central Europe to the dry areas of the Mediterranean.

In general, the weather databases with an adequate resolution for the study of fast extreme precipitation events (EPEs) do not have an appropriate sample period length to apply mathematical methods that can help to directly understand the trends of these events. Knowing with greater accuracy the future scenarios of temperature in relationship with the current global warming, some works studied the relationship between temperature and rainfall to define also future scenarios of rainfall regimes.

In this study, we analyzed a database with more than 1,000 meteorological stations, most of them equipped with both rain gauges and thermometers located in north and central Italy. The selected database has a low rainfall accumulation period (RAP) that made it possible to analyze the relationship between temperature and rainfall in unprecedented detail the relationship between temperature and rainfall, distinguishing between fast and long events related to rainfall intensity.

The results show different relationships between rainfall and temperature according to seasons, RAPs, rainfall intensity, and geographical factors. With an increase in the temperature, the wet season shows a general increase in rainfall and a higher surge for intense and fast events, while the dry season is characterized by a general rainfall decrease of the loss of intense and longer-lasting events, experiencing fast and more intense rainfall events increase. This behavior has repercussions on the water resource, inducing a future decrease in the water available, an increase of the EPEs, and thus an extremization of the climate during the dry season in northern and central Italy.

Into the mega-monsoon: yearly flood dynamics of the Nile River during the last African Humid Period

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Seasonal floods are life-supporting events in the Nile Valley and have been crucial to the development of complex societies. Past and present populations depend on their occurrence but the alteration of fluvial dynamics under climate change remains elusive. In this presentation, we will explore the changes in flood dynamics of the Nile River during a period of high monsoon activity known as the African Humid Period (during the early Holocene). Using a unique sediment core from the Nile deep-sea fan that contain well-preserved marine varves (i.e., annual layers), we were able to track the changes in flood dynamics at annual resolution between 9.5 and 7.5 ka BP. This remarkable 1500 yr-long annual flood record from the Nile River allows us to investigate fluvial regimes under high rainfall intensity and determine the main climatic forcing driving flood dynamics.
Varve thicknesses vary drastically through time between 0.3 and 13 mm with significant changes at 8.2, 8.9 and 8.7 ka BP occurring within a few decades. These variations suggest large modifications in the erosional regime of the Nile, leading to the deposition of variable amounts of sediments on the margin. In particular, a large variability is observed in intervals with overall thicker flood layers between 9.5 and 8.7 ka BP, which leads credence to the hypothesis of a more variable Nile flow under warmer climates. In addition, time-series analyses demonstrate a persistent El Niño-Southern Oscillation (ENSO) fingerprint throughout the record. Climatic simulations at 9 ka BP show that the Pacific state was probably shifted towards La Niña conditions, driving larger rainfall on the Nile watershed. In the presentation, we will discuss the potentiality that the large variability observed was related to a more variable ENSO or to amplification processes during a mega-monsoon interval.

The limitations of uniformitarianism: the glacial aridity paradigm

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The climate of the last glacial maximum (LGM, ~23-18 ka) is routinely interpreted as substantially drier than today, in most subtropical regions. This perception is largely the result of interpreting fossil pollen evidence of widespread LGM treelessness and/or reduced vegetation biomass, and evidence for increased dust deposition, within a uniformitarian framework. However, it is increasingly clear that the 'arid' appearance of LGM vegetation – treelessness, or lower inferred biomass – can at least partly be explained as an expression of C3 plants' physiological responses to, and reduced water-use efficiency under, low atmospheric CO_2.

An alternative proxy for past moisture balance which is largely independent of vegetation structure or biomass is the simple growth of speleothems, which demonstrates a positive moisture balance, at least on ~seasonal timescales. In several seasonally-dry Southern Hemisphere subtropical regions, speleothems grew through the LGM. This growth seems to contradict interpretations of arid climates that have often been based on interpreting changes in vegetation structure from fossil pollen records.

Here we present LGM-aged fossil pollen records recovered from U-Th-dated speleothems from Naracoorte (South Australia), and Weelawadji and Mammoth caves (Western Australia), regions which today experience moderately dry, mediterranean-type climates. These records show substantial changes in vegetation structure, including substantially reduced tree-cover, consistent with 'conventional' LGM wetland pollen records in the region. However, our records include a number of shrub and herb taxa that indicate moisture availability equal to or higher than today, despite striking reductions in LGM plant biomass. Higher-than-modern moisture availability at these sites is consistent with published climate model simulations. These simulations indicate that, in many regions, even where LGM precipitation was lower than today, globally widespread reductions in evaporation contributed to a more positive LGM moisture balance.

Session 104: Novel molecular tools (biomarkers and DNA) in climatic and environmental archives – challenges, advances, and prospects

Testing the limits of lacustrine faecal lipid biomarkers as tools to document human presence in the Alaskan landscape

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In recent years there has been an expansion of the use of faecal sterol biomarkers to generate records of human occupation in the landscape from lake-sediment profiles. Faecal steroid biomarkers (5β-stanols, bile acids) were initially used in archaeological settings in the late 1980s and have since been successfully developed and applied to characterise the presence of humans and animals from archives of concentrated faecal waste e.g., coprolites and archaeological soils. Faecal steroids are well-preserved within lake sediments, indicating they have the potential to be direct archives of anthropogenic activity. The application of faecal biomarkers within diffuse depositional environments of lake basins, however, presents new methodological challenges, which are currently being overlooked.

We investigate the efficacy of lacustrine faecal biomarkers to trace human presence within the landscape using steroid records generated from a lake in central Alaska, with independent records of human activities over the past 2000 years. Comparisons of steroid data obtained from modern dung, catchment soils and lake sediments show that the use of sterol concentrations alone is insufficient to conclusively characterise faecal input within lake sediments. Whilst diagnostic stanol ratios can identify faecal matter, the standard archaeological threshold values require systematic testing for robust application in aquatic sediments, to account for processes such as dilution and *in-situ* primary productivity. Findings from the modern environment demonstrate that stanols alone are insufficient for characterising faecal inputs to lake cores, but that the incorporation of both stanols and bile acids, the latter of which are solely produced from digestive processes, is reliable. Overall, we demonstrate that lacustrine faecal biomarkers are effective tools to trace human presence when corroborated with additional proxies of anthropogenic impact, historical records and/or archaeological evidence. However, we highlight uncertainties relating to lake-taphonomic processes that must be addressed to optimise applications of this proxy within aquatic sedimentary archives.

Reconstructing Holocene human-climate-landscape interactions in semi-arid Mongolia using multi biomarker analyses

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Semi-arid regions are highly sensitive to global warming and human activity, and a better understanding of past climatic changes and anthropogenic influences in such regions is therefore essential. In this context, biomarker analyses have great potential to strongly enhance our knowledge about human-climate-landscape interactions since they are source-specific and direct indicators for hydrological and temperature dynamics as well as anthropogenic landscape changes.

Here we present potentials and pitfalls of biomarker analyses in two high-altitude lakes from the Mongolian Altai (Khar Nuur) and Khangai Mountains (Shireet Naiman Nuur). At both sites, robust chronologies have been established, spanning the last 4.2 and 7.4 cal. ka, respectively. We aim at i) reconstructing hydrological conditions using compound-specific hydrogen isotopes (δ^2H) of *n*-alkanes, ii) reconstructing temperature changes with long-chain alkenones and iii) tracing anthropogenic impact in the lake catchments with polycyclic aromatic hydrocarbons (PAHs) and fecal sterols/stanols.

While the lacustrine sediments of our investigated lakes comprise a mixture of terrestrial and aquatic components, our results show that terrestrial *n*alkanes (i.e., C_{31}) from leaf waxes of terrestrial plants incorporate the δ^2H signal of the local growing season precipitation. Aquatic *n*alkanes (i.e., C_{23}) produced by algae and aquatic macrophytes incorporate the δ^2H signal of the lake's water, which can be strongly modulated by evaporative enrichment. The isotopic offset ($\Delta_{aq\text{-}terr}$) between δ^2HC_{23} and δ^2HC_{31} is a valuable indicator for evaporation changes in the lake catchments and shows distinct hydrological changes at our investigated sites. Long-chain alkenones, which are produced by the so-called Group I phylotype haptophyte algae, are abundant and seem to record changes in growing season temperatures and the timing of alkenone production rather than changes in mean annual temperatures at our high-altitude sites. The PAH perylene, which is thought to be produced by fungal species in soils, is also abundant in our lake sediments likely record phases of enhanced runoff and erosion. Fecal sterols/stanols are currently being analyzed and will finally complement the overall picture of human-climate-landscape interactions at our investigated sites.

Investigating the potential of amino acid analysis and peptide mass spectrometry in identifying burning in Quaternary fauna

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Abstract

The excellent protein preservation recently discovered in Pleistocene tooth enamel has opened up exciting avenues for building chronologies (amino acid dating), evolutionary phylogenies and determining sex (palaeoproteomics) of mammalian fauna in archaeology and palaeontology. However, if samples have been heated, this will speed up protein degradation and therefore lead to loss of information. Heating events can either be anthropogenic, or through natural processes such as volcanism and wildfires.

To study this in detail, artificial high temperature heating experiments on tooth enamel from three Pleistocene subfossil fauna (Mammuthus primigenius, Coelodonta antiquitatis and Hippopotamus amphibius) and three modern taxa (Equus caballus, Bos taurus, Capra hircus) were conducted. To study the effect of high temperature heating, two techniques were used: reversed-phase high performance liquid chromatography (RP-HPLC) which provides information on amino acid concentration, composition, racemisation and peptide bond hydrolysis; and liquid chromatography with tandem mass spectrometry (LC-MS/MS), which yields peptide sequence and diagenetic post translational modifications (PTMs). Upon heating, significant changes in protein composition were observed for all samples, which were characteristic of heating rather than low temperature burial diagenesis. These patterns of degradation therefore enable us to develop a tool to identify burnt samples, as well as help us understand the potential for individual heated samples to yield useful proteomic or geochronological data.

Insight into the Holocene phytoplanktonic community of the Baltic Sea: a multi-method approach

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The reconstruction of past environments is a challenging and rapidly developing research field. As environmental conditions determine the occurrence of organisms, remains of these organisms can be used as proxies of past environmental conditions. However, most organisms rapidly decompose after death either before or after deposition into sediments, and this process leaves only molecular remains behind, such as lipids and DNA. Further, both decaying organisms or molecular remains might be passively transported before deposition into sediments. This source-transport-sink process complicates the application of molecular remnants as proxies of past environments.

As a semi-enclosed, shallow, geologically young sea located close to the centers of the Industrial Revolution, the Baltic Sea faced anthropogenic pressures earlier than most other marine ecosystems. As human pressures caused ecological degradation in the Baltic Sea, biomonitoring started decades ago, leading to good monitoring data especially for phytoplankton communities. The latter are well-established indicators for ecological changes since they are sensitive to diverse environmental stressors. The existence of long-term observational data makes the Baltic Sea an excellent model to investigate the potential of DNA and lipids derived from phytoplankton as proxies of paleoenvironments.

Here, we compare sedimentary ancient DNA (seda DNA) and lipid biomarker data from Baltic sediments with phytoplankton monitoring data from the last 50 years. We aimed to 1.) detect possible lipid sources 2.) calibrate seda DNA and lipid biomarkers on monitoring data 3.) apply the gained knowledge for paleoenvironmental reconstructions of the Baltic Sea. We extracted seda DNA as well as lipids from several horizons, amplified DNA with primers targeting representatives of major taxonomic groups - diatoms, cyanobacteria and dinoflagellates, and sequenced amplicons on an Illumina platform. We measured lipid biomarkers for phytoplankton using gas chromatography coupled to mass spectrometry. The results allow us evaluating how precisely seda DNA marker genes and lipid biomarkers reflect observational data of phytoplankton, reconstructing Baltic Sea past environments and understanding how phytoplankton communities responded to the changing environments.

eDNA analyses from river sediments to investigate its potential to trace erosion hot spots

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In recent years, the number of studies using sedimentary ancient DNA (sedaDNA) analyses for palaeoenvironmental/climatic reconstructions or for understanding human-environment interactions has increased dramatically. Technical progresses, promotion of the great potential of the tool to push the boundaries of our knowledge on the past composition of life and strengthening of the scientific community, notably through the sedaDNA society, explain this success.

However, there are still many unknowns about the ability of the tool to reflect past environments, taxonomic composition and diversity. When looking at terrestrial organisms from extracellular DNA (exDNA), one crucial question concerns the processes that are governing the DNA transfer and thus the origin of the sub-fossil sedDNA. The now-preferred hypothesis states that most exDNA is bound to mineral/organic or organo-mineral particles and thus transferred through erosion processes, making the community composition a potential signature of the sediment origin. One consequence of this statement is that, in a sediment cascade system, covering several biomes with contrasted vegetation, the sedaDNA could theoretically be used as a tracer of the sediment origin. In this study we aimed at investigating this potential.

In this aim, we applied a DNA metabarcoding approach targeting plants to exDNA extracts from modern sediments of the Arve and Rhône Rivers (six samples) and their tributaries (eight samples) upstream of Lake Bourget (a hard-water peri-alpine lake). We performed a Non-metric multidimensional scaling analysis to assess the differences/similarities in the floristic composition of the different tributaries and of the Arves and Rhône Rivers. Because the tributaries drain different vegetation belts characterized by specific taxa, they show distinct signatures. Interestingly, the signature of most tributaries was also detected downstream in the main rivers (Arve or Rhône). However, other tributaries, at the time of sample collection, did not appear to contribute to the DNA signal of the main river, raising the question of their sedimentary contribution. However, despite this remaining complexity which still needs to be addressed, these results strongly support the potential of sedimentary DNA as a new proxy to track erosion hot spots.

Ancient DNA from sediments identifies past ecosystem engineering species

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Before humans assumed the dominant role in engineering streams and floodplains, native taxa controlled ecosystem engineering and surface change within river-floodplain systems. However, little is known about this pre-human, natural condition of European rivers and their floodplains. Furthermore, for periods where human activity was a major driver of river floodplain evolution, it is often challenging to distinguish between sites affected by human vs faunal behavior in the absence of physical evidence. In this pilot study, we aim to reconstruct the pre-human environmental condition of central European, low order streams and their floodplains. Further, we develop a methodology to identify the major drivers of ecosystem engineering at specific riparian sites. We selected three research sites in central Europe, and reconstructed the pre- and post-human palaeo-environmental conditions at these sites.

We analyzed ancient DNA from sediments (sedaDNA) and tested for the presence of specific wetland vegetation. These abundances are then compared with an analysis of botanical macroremains from the same sediments. We also test for animal ecosystem engineers, such as the beaver, water vole and aurochs, as well as domestic species. Overall, aDNA was able to identify the presence of many ecosystem engineers, with clear signatures separating the pre- and post-human ecosystems. While in the more human modified floodplain mammalian engineers dominate, vegetation dominates the record of the more natural side. In combination with a detailed chrono-stratigraphy this study shows how animal husbandry dominates land-use over a riparian forest at the more natural setting.

We additionally compare three methods for enriching and analyzing ancient sediment DNA, including novel methods for identifying the less abundant natural mammalian taxa that are missed using standard approaches. Locating where and when these species were present will not only give us an understanding of the natural and most sustainable environmental conditions of riparian areas, but will also create a baseline for a better understanding of subsequent human-environment interaction

Towards a new fossil proxy for UV-B radiation: Reconstructions of UV-B absorbing compounds from Quaternary sediment sequences

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Large variations in ozone and UV-B radiation at ground level are thought to have occurred in the past, with potentially major implications for climate, human societies and ecosystems. Although UV-B radiation is an important variable for understanding those processes influencing life on Earth, at present it remains challenging to reconstruct changes in UV-B radiation at the Earth's surface beyond the period covered byinstrumental measurements of the 20th century.

Since the 2000s, researchers have suggested that chemical sunscreens produced by plants, and which are also found in the walls of pollen grains and subsequently buried in lakes and bogs over thousands of years, may be used to reconstruct UV-B radiation that was received by these plants during their lifetime. However, although the evidence base for a chemical response of UV-B absorbing compounds spans a variety of species under a range of experimental settings, there remains uncertainty about whether pollen-chemical variations reconstructed from sediments respond to changing ratios of UV-B radiation: Total Solar Irradiance (e.g. as a result of changing atmospheric chemistry) or whether fossil reconstructions are more likely to reflect changes in total solar irradiance. This makes it difficult to generate precise reconstructions that can be be used in Earth system models and studies of the effects of UV-B radiation on the biosphere in the past.

Here, we assess the potential for reconstructing UV-B radiation through fossil sequences in the Holocene. Specifically, we investigate the utility of the proxy for a range of applications, including (i) whether variations in the UV-B-absorbing compound *para*-coumaric acid can reflect long-term solar forcing linked to changes in total solar irradiance; (ii) whether short-term variations in atmospheric chemistry resulting from large volcanic eruptions can be detected in the signature of UV-B absorbing compounds from annually laminated sequences.

Session 105: Quaternary mapping across the world and the IQUAME European experience

The Quaternary of Austria: Stratigraphy, processes and mapping approach

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***1.** Geosphere Austria*

Austria's diverse landscape results of the interplay of tectonic processes and climate change. The final shaping occurred during the Quaternary (the last 2.58 Ma) and is characterized by strong global climatic variations between glacial and interglacial conditions affecting the heterogeneous landscape and its archives depending on the magnitude and duration of the climatic signal.

The oldest deposits are loess-palaeosol sequences (LPSs) documenting the onset of loess accumulation at the beginning of the Quaternary. The Early Pleistocene record consist of LPSs and gravel deposits with no indication of a glacier advance and is followed by deposits of four known major glaciations, namely Günz, Mindel, Riss and Würm (from oldest to youngest). These Ice Ages were characterized by a large complex of transection glaciers, i.e. an interconnected system of valley glaciers covering large sections of the Eastern Alps with glacier tongues terminating in the Alpine foreland. All four glaciations left Glacial Sequences genetically linking tongue basins with (subglacial) till, terminal moraines and terraces with different degrees of weathering and characteristics of cover beds (e.g. LPSs).

Based on geochronological data, relations between type and magnitude of the global climate signal and the amount of reconstructed sediment production, the following correlation with major phases of global glaciations is used: Günz (MIS 16), Mindel (MIS 12), Riss (MIS 6) and (Late) Würm (MIS 2). Detailed knowledge of the Last Interglacial-Glacial cycle (130-12 ka) allows establishing models for climatically controlled sedimentary processes and glacier expansion in the longitudinal valleys of the Eastern Alps. Overdeepened valleys and increased relief leading to different types of mass movements are also a legacy of glaciations.

From the formal stratigraphic point of view, the Austrian record of Quaternary sedimentary units (van Husen & Reitner, 2011, 2022) resembles a compound stratigraphy including aspects of lithostratigraphy (lithic characteristics) as well as morphostratigraphy and allostratigraphy (discontinuities/unconformities) for the definition of different units. The youngest phase of the Quaternary (Würm Lateglacial to Holocene) is documented on geological maps not by stratigraphic units but mostly by lithogenetic units according to the "Terminology for geological mapping of Quaternary and mass movements in Austria" (Steinbichler et al. 2019).

METIQ: The Quaternary Map of Italy (1:500.000 scale) and the dynamic evolutionary model of Italian landscapes

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Ahead of the INQUA 2023 in Rome, the Italian Community of Quaternary scientists gathered to produce the first Quaternary Map of Italy at 1:500.000 scale.
Italy lies on one of the most geodynamically active sectors of the Mediterranean and most of its landscape has been modelled by Quaternary geological processes. For this reason, the Italian Quaternary geological, palaeoenvironmental, geomorphological and neotectonic records are the most important proxy for evolution of Italian landscapes and ecosystems, as well as for applicative purposes as most of the population and economic activities take places on Quaternary deposits.
The existing mapping archives of Quaternary deposits in Italy are discontinuous and inherently nonhomogeneous due to different national and regional mapping projects developed during the last 2 centuries with different aims and scale of representation. Stratigraphical correlations developed through time using complex litho-, chrono-, and bio-stratigraphical criteria made correlations in terrestrial Quaternary systems somehow problematic. This was due to the fragmentary nature of the record and to lack of reliable dating techniques covering the full range of Quaternary time. Terminology defining the chrono-stratigraphical setting was often based on local or old-fashioned schemes and the need for a common language/terminology/methodology is strongly necessary to harmonize and share among Quaternary scientists the basic geoscientific information. To set the regional names and subdivisions avoiding as much as possible the problems due to local terminology, the Quaternary Map of Italy will focus on the main Quaternary series and stages as assessed by IGSC. This approach should give a summary and overview of the main characters of the subseries/stages across Italy.
A spatial database in geodatabase and geopackage formats has been prepared for data storage and management. Code lists have been prepared to facilitate data entry of new information relating to the coding provided by the Project.
The outputs will be a printed map (7 sheets at 1:500k scale) and an open GIS-based Web platform allowing the retrieval of all the attributes and related values, and the interoperability with existing Quaternary-related thematic databases such as landslides, earthquakes, Quaternary key-sites (i.e. GSSPs) etc.

The International Quaternary Map of Europe and Adjacent Areas: an European project with many facets

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The project of the International Quaternary Map of Europe project (IQUAME 2500) is a major international initiative coordinated by the Federal Institute for Geosciences and Natural Resources (BGR) under the auspices of the CGMW (Commission of the Geological Map of the Word, Sub-Commission Europe) and with support of INQUA. The first edition of the map (BGR and UNESCO, 1967 – 1995), a paper map, was also compiled in international cooperation and within a specific INQUA Commission for the Quaternary Map of Europe. The new map is being compiled as a Geographic Information System and will be available on-line. It will show the distribution of Quaternary deposits across the entire European continent and Quaternary off-shore geology.

The IQUAME is collecting information on numerous aspects of the European Quaternary:

- lithology and geochronology of Quaternary depositional units,
- genetic descriptions of the units,
- maximum extent of the ice sheets (Weichselian, Saalian, if possible Elsterian),
- directions of ice movement,
- extent of Arctic sea ice,
- postglacial rebound,

- off-shore Quaternary information (in cooperation with the EU EMODnet Geology project),
- active faults,
- extent of permafrost,
- key localities (e.g. geologically and anthropologically interesting sites).

IQUAME 2500 is a multinational cross-boundary project and international collaboration with research organisations and national geological surveys throughout Europe is essential. Scientists from over 40 countries are participating and a scientific board of Quaternary researchers ensures the scientific quality of the resulting map layers. BGR is developing the map mainly using the participants' contributions, but also current publications and maps and other project' results.

The participation of numerous international partners is a challenge and requires data harmonisation regarding semantics, structure and geometry. To achieve this aim, common standards and guidelines needed to be set up and applied by all participants: structured vocabularies to describe the IQUAME's contents, a common topographic base, technical procedures to include the map data and guidelines to aid the partners to submit their data to the project.

Finally, the IQUAME map will show a synthesis of the current status of European Quaternary geological mapping and research, together with numerous related scientific facets of the Quaternary history of the continent.

General Quaternary Geological Map of the Slovak Republic (1 : 200 000), Geological Map of the Danube Lowland – Danube Flat (1 : 50 000) and Geological Map of the Danube Lowland – southeastern part 1:50 000

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Geological maps are an essential underlying layer that are used in analyzes and applications in the environmental sector, economic and administrative activities of the state administration. The creation of a geological map of a region is a multi-year process of basic and regional mapping and research. The coverage of the territory of the Slovak Republic with geological map works has lasted for more than 50 years.

General Geological Quaternary Map of the Slovak Republic 1:200 000 offers a qualitative assessment of individual genetic types of the Quaternary deposits of the Western Carpathians and Pannonian Basin on the territory of Slovakia. It shows the resulting stratigraphically assessed arrangement of the Quaternary cycle of a geodynamic development of this territory and its impact upon the nature, landscape, and mode of distribution of the relevant genetic types.

Geological Map of the Danube Lowland – Danube Flat 1:50 000 and **Geological Map of the Danube Lowland – southeastern part 1:50 000** represents the latest and most extensive mapped region in the history of geological research and mapping, with an area of 3 010 km^2 and 1 407 km^2. Maps provide a very detailed picture of the surface geological structure through more than 20 500 allocated polygons. The maps show mostly Holocene to Pleistocene/Holocene development, give an image of the geological structure, geological and structural-tectonic development of the whole Cenozoic sedimentary infill, including approximate reconstruction of the tectonic units of its pre-Cenozoic basement of the basin. The second map represents an important region with loess cover and well-developed fossil soils. The work included geophysical, hydrogeological, pedological, bearing, and environmental research; using airborne LiDAR datasets, laboratory - chemical, grain and isotopic analyzes; AMS ^{14}C, OSL, and cosmogenic ^{26}Al/^{10}Be burial dating.

These maps are compounded on the genetic-stratigraphical principle, lithological fill, and the composition of sedimentary fill rocks. And contain other annexes: text explanatory notes, map legend, scheme of the map sheet layout, lithostratigraphic table of Quaternary and geological cross-section through the Quaternary fill.

Revision of the Mid-Pleistocene ice sheet limits stimulated by geological mapping in the Polish-Belarusian-Ukrainian border region

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A reduced sequence of the Quaternary deposits in the Polish-Belarusian-Ukrainian border region and a restricted access to the border area have been both a serious problem in the past to attain a stratigraphic correlation of the Quaternary deposits and ice sheet limits in this area. Results of previous research of geological deposits and landforms, supplemented with numerous research archival boreholes permitted us to focus field works in several key sites (exposures and drillings). Sites with the Mid-Pleistocene glacial deposits were crucial for stratigraphy of the study area, the same as deposits of the Mazovian Interglacial (Holsteinian). Samples collected at key sections were subjected to lithological, geochemical, pollen and malacological analyses, and OSL and ^{14}C dating. Based on examination of several key sites and revised geology, 2 geological maps were prepared within the frames of the research project no. 2017/27/B/ST10/00165, funded by the National Science Centre in Poland. Sheets of the Detailed Geological Map of Poland (1:50 000) and the geological maps of Quaternary deposits published earlier for each of the countries (1:200 000), were used and after the selected field verification the final geological map (1:250 000) was prepared. Results enabled to verify origin and stratigraphy of deposits in the studied area. A reliable cross-border correlation of stratigraphic subdivisions enabled a considerable reduction of the Mid-Pleistocene stratigraphical units in this area, including glacial sequences of the Odranian (Saalian) and Sanian 2 (Elsterian) glaciations, as well as lake and fluvial deposits of the Mazovian and Ferdynandovian (Cromerian III-IV) interglacials. Therefore, recent investigations in the Polish-Belarusian-Ukrainian border region fundamentally revised the regional stratigraphy and palaeogeography, and proved univocally that the subordinate Warta Stadial was the most extensive during the Odranian Glaciation in this area. The study area seems to be a key one for Quaternary stratigraphy and for regional stratotypes in Central Europe.

Georgia (SW Caucasus) in Quaternary

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The lithosphere of Georgia and the Black Sea–Caspian Sea region represents a collage of Tethyan, Eurasian, and Gondwanan terranes. During the Late Proterozoic–Early Cenozoic within the convergence zone, there existed a system of island arcs and back-arc basins characteristic of the precollisional evolution of the region.

The marine basins of the Tethys in Late Cenozoic were replaced by Transcaucasian basins of euxinic type (the Paratethys) and, later, by continental basins with subaerial condition of sedimentation.

Starting from the Late Miocene, volcanic eruptions in the central part of the region occurred under subaerial conditions.

The geochronological and stratigraphic schemes and correlations of the Mediterranean province are based on the combined interpretation of data from various fields of geological sciences.

The Cenozoic collision between the Eurasian and Arabian continental masses was coeval with the Cenozoic magmatic activity.

The Pleistocene volcanic rocks related to the transverse Van– Transcaucasian uplift. belong to the calc-alkaline basalt–andesite–dacite–rhyolitic series.

Near the town of Dmanisi the Paleolithic objects were found. The complex of fossils identifies the age of enclosing rocks as the Eo-Pleistocene corresponding to the Apsheron regiostage. In the same sediments the remains of hominides were found identified as the representative of *Homo Erectus Ergaster* . The age of the basaltic lavas directly underlying the bone-bearing horizon was determined by $^{40}Ar/^{39}Ar$ ranging from 1.95 Ma to 2.04 Ma.

The Holocene deposits with the Late Pleistocene ones are developed almost everywhere and are represented by different facies. Holocene-Upper Pleistocene deposits are plotted on the 1:200 000-scale geological map of Georgia according to the guideline “Review of the 1:2.5 Million International Quaternary Map of Europe 2014, and actualized in 2016 (Asch, K., Gdanic, A., Muller A. IQUAME2500)”. This document contains the general legend of the IQUAME-project and shows all the map symbols applied to GIS program.

Mud volcanoes, with several-meter-high cones having a wide area of mud seepage, are met only in outer Kakheti.

The Earthquake indicate active tectonics in Georgia Some of the major earthquakes have proven to be devastating.

METIQ: the last interglacial transgression (Tirreniano) for the Quaternary Map of Italy (1:500.000 scale). Five hundred points that indicate the breath of the Italian coasts

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For the Congress INQUA 2023 in Rome, the Italian Community of Quaternary scientists produced a Quaternary Map of Italy at 1:500,000 scale. In particular, for the whole Italian coastal areas, a database was compiled using the outcrops of the MIS 5.5t marine transgression. For the compilation of this important time-slice, we used many outcrops represented by numerous fossil forms and deposits in the Italian coasts. We used three important databases: Walis (World Atlas of Last Interglacial Shorelines), Ferranti and Lambeck. Data resulting from these databases, (those from numerous recently published works have been added) but above all we re-evaluated (in order to fit METIQ required database), the elevation, the age, the measurement error, the relationship with original sea level, and calculated uplift rate at each site. The time slices 119 ka BP was used as maximum MIS 5,5 highstand for the central Mediterranean and corrected with the local GIA (isostasy). For each of the 500 listed sites, the accurate elevation is defined through well-known markers (the best are considered fossil tidal notches and lagoons sediments containing fossil *Cerastoderma*), coupled with a refined age assessment locally supported by radiometric dating, (OSL, ESR, Ur\Th, Aminoacid, ecc.). The chronological attribution in the Mediterranean is greatly facilitated by the presence in numerous fossil deposits of the Senegalese fauna also containing *Strombus bubonius* (whose name has been changed to *Persistrombus latus* and again *Tetystrombus latus*) this gastropod appears to have entered the Mediterranean only during the MIS 5.5 and then extinct. (except for a small area around the Strait of Gibraltar). All these sites provide robust constraints on deformation. Significant alongshore differences in site elevation between +175 and -125m a.s.l. resulted from the interplay of regional and local tectonic processes, including faulting and volcanic deformation.

Session 106: Evolution of coastal environments under natural and anthropogenic processes: the role of geoscience

Data-driven shoreline modeling - historical remote sensing and forecast analyses

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In this presentation, we describe a novel, data-driven approach for extracting satellite-derived shorelines, for constructing shoreline change timeseries, and for projecting future shoreline positions. First, to build satellite-derived shoreline datasets, we developed an image-to-image translation generative adversarial network to map RGB satellite imagery into segmented land/water images, after which shorelines are extracted via a contour tracing algorithm (marching squares). This model incorporates over 25,000 LANDSAT 5, 7, 8 and Sentinel-2 images from the Delmarva coast (USA), the New Jersey Shore (USA), Long Island (USA), and the North Tuscany Littoral Cell (Italy), spanning from 1984 to 2022. Next, we generate shore-normal transects at 15-m alongshore intervals, which we use to compute intersection points with the extracted shorelines to construct timeseries of cross-shore position along a given transect. With these timeseries, yearly linear shoreline change trends are computed through ordinary least squares, with maps illustrating the average retreat/accretion trends across broad (several km to tens of km) coastal regions. Last, we incorporate long short-term memory networks on individual cross-shore position timeseries datasets to learn the behavior of each timeseries and then project future cross-shore positions (with bootstrapped uncertainties) several decades into the future. For select regions, the projected cross-shore positions at each transect are then merged together into full two-dimensional shorelines (with uncertainty polygons), for each projected time period. All software components developed for this project are open-source and freely available, as are the trained models and labelled satellite imagery. In the future, we hope to expand this methodology to other coasts worldwide, as well as integrate higher spatial and temporal resolution imagery into this framework.

Chronologically constrained Holocene reef growth, modern reef disturbance regimes and geomorphological controls on future reef potential; Southern Great Barrier Reef, Australia

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In the face of future challenges to coral reefs it is important to understand responses to climatic and environmental changes at multiple spatial and temporal scales. Yet, there is currently a disconnect between understanding past reef histories, modern disturbance regimes, and the potential of future reef growth. To bridge the gap between biological and geological timescales we present the results of ~500 U-Th dated corals obtained from reef flat and slope matrix cores, fossil microatolls and death assemblages from eleven continental island fringing reefs in the Keppel Islands, southern Great Barrier Reef (GBR).

Reef flat cores show that coral initiation occurred prior to 7500 years before present (yr.BP-1950), although not contemporaneously among sites. Following initiation accretion rates were comparable to reefs elsewhere on the GBR, but rapidly outpaced average rates reported for the inshore GBR in the subsequent 1500 years when sea levels were higher, and sea surface temperatures were ~1°C warmer. After 5500 yr.BP a reduction in net accretion rates was likely driven by a combination of climatic and environmental changes, as well as geomorphological constraints. Reef slope cores show limited accretion from ~500 yr.BP to present at two reef sites suggesting these reefs had reached their geomorphological limits, with coral growth now restricted to a thin veneer that is more prone to disturbance.

Death assembles ages ranged from ~6300 yr.BP to modern, with 88% of total ages occurring post-1945AD. Temporal kernel density estimates (kde's) derived from coral death assemblages were variable among sites until a multi-site peak centered around the 2006AD bleaching event, supporting observations of unprecedented modern regional scale mortality. However, when spatial kde mapping of death assemblage data (11 sites) is compared with observed monitoring of bleached coral (7 sites) our data suggests coral mortality was far more widespread than captured by observations.

This study provides a unique insight into the history of a high latitude reef region and suggests whilst future sea level rise may increase reef accretion potential in the future, a deterioration in ambient water quality, repeated SST extreme events and site-specific geomorphological constraints may impede reef growth potential in the region.

Seascape-landscape morpho-sedimentological variations at a tourist beach along the Northern Tuscany littoral cell (Italy)

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We present data from a bathymetric survey performed along the Northern Tuscany littoral cell (Italy). This area has been marred by serious erosion for the last 100 years, especially north of Forte dei Marmi. The survey was performed with a Norbit iWBMSe multibeam echosounder, which is a compact and portable multibeam operating at 400 kHz with an integrated PosMV SurfMaster IMU and dual GNSS-aided inertial navigation system. An area of more than 130 hectares was mapped in very shallow waters ranging from -2 to -8 m. These surveys generated extremely high detail of the seafloor with less than 25 cm/pixel gridded resolution and even finer ungridded soundings. The subaerial portion of the beach was also surveyed. The topography was obtained by Structure from Motion using a DJI Mini 2 drone equipped with a camera (12MP 1/2,3" CMOS sensor and 24mm focal length) combined with ground control points, which provided a high-resolution reconstruction of the beach morphological elements. Additionally, sediment textural analyses were carried out to define the grain-size variation along backshore-offshore transects. The survey data revealed a dramatic seascape of crescentic sand bars with wavelengths of approximately 300 m and heights of 3 about m. Both the sandbar wavelength and amplitude are variable along the survey domain. These sandbars are indicative of an intermediate state beach morphology and play a tremendous role in governing the transformation of wave energy from offshore to the beach. Additionally, these sandbars influence patterns of increased or decreased erosion/wave energy on the beach. This morphology contrasts to that which was reported by previous authors who described an overlapping portion of this area as having a dissipative profile "with non-rhythmic parallel/meandering bars". The full dynamics of these sandbars are not presently known but they may likely shift in response to changes in longshore drift and energetic storm events, thereby potentially having widespread impact on the wave conditions that govern the nearshore and shoreline. These datasets underscore the importance of monitoring the seascape adjacent to the coastline as well as shoreline trends to help coastal managers make the right decisions on the management of this touristic area.

Estuarine salt marsh evolution during the Late Holocene driven by complex natural and anthropic forcing

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Estuaries are very complex transitional environments, being often difficult to disentangle the different forcing factors responsible for their evolution when we analyze these systems at a millennial time scale. Similar sedimentologic responses to different types of processes, mixing of sediments by bioturbation, erosional gaps, distinction of time and space sedimentation rates, and sediment dating, are among the difficulties faced when studying recent evolution of the intertidal depositional areas.

In this study, the Late Holocene evolution of salt marshes formed in the estuarine margin of the Tróia sand spit (Sado estuary) will be presented. This area has been chosen given: (1) the different geomorphologic situations present; (2) the well-known time constrain derived from the already identified Tróia sand spit growing phases in the last 6500 years and (3) its Roman archeologic occupation.

Several cores have been retrieved from different sub-environments high and low marshes and tidal flats in three locations (subareas), allowing comparison between subareas and across the altitudinal transects (subenvironments). ^{14}C dating of the base of the cores show that the sedimentary columns deposited since mid-12th century in the northern (and more recent) tip of the spit and ca. 2000 cal BP in the southern (older) area. The analyses of ^{210}Pb and ^{137}Cs allowed deriving accretion rates of about 3.0 mm/year in the last 70 years, independently of the marsh location and height.

Several sedimentologic and geochemical proxies have been used to characterise the marsh paleoenvironmental evolution. Sediments are essentially organic mud, with some sand intercalations in low and high marsh and are sandier in the tidal flats. Organic carbon is essentially POC marine water in the tidal flats and low marsh (which may also include DOC marine water) and a mixture of DOC marine water and terrestrial plants C3 in the high marsh. Besides similar general tendencies of sedimentation in the different sub-environments, differences between subareas have been found, related to natural events and/or anthropic activities and will be discussed. This work was funded by the Portuguese Fundação para a Ciência e a Tecnologia (FCT) I.P./MCTES through national funds (PIDDAC)–UIDB/50019/2020-IDL, PTDC/CTA-GEO/28412/2017 (CLIMARES) and Ph.D. Grants PD/BD/142781/2018 and PD/BD/106074/2015.

Late Holocene evolution of Western Mediterranean Lagoons: La Albufera de València (Iberian peninsula), s'Estany des Peix and s'Estany Pudent (Formentera, Balearic Islands)

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Mediterranean coastal lagoons are dynamic ecosystems and their Holocene depositional evolution has been controlled by climatic fluctuations, sea level changes and anthropogenic pressures. In this work, we present the results of a multidisciplinary study of new sediment cores from three sites, one in the Iberian Peninsula coast (la Albufera de València, 39.333189, -0.355318), and two in Formentera a Balearic Island (s'Estany des Peix, 38.726050, 1.410906 and s'Estany Pudent, 38.724978, 1.436870). La Albufera de València has been exploited for its hunting and fishing resources since the Neolithic, and it has been heavily altered during the last century due to rice cultivation and industrial activities. We aim to reconstruct the environmental and climate conditions during the late settlement of Formentera (the oldest megalithic construction dates from 4000 BP) and the depositional evolution of the coastal sites.

According to our ^{14}C age models, the recovered sequence of s'Estany Pudent spans the last 7.5 ka, s'Estany des Peix sequence covers the last 5.7 ka and La Albufera de València record encompasses the last 4 ka. The sedimentary sequences have been studied following a multiproxy strategy including sedimentary facies, elemental geochemistry and isotopic analyses in carbonates and organic components.

S'Estany Pudent was transformed from a marsh to a coastal lagoon due to a marine transgression around 7 ka ago. The sequences illustrate depositional changes due to varied marine influence and intercalated extreme events (floods, storms). In the three lagoons, the most notable changes occurred in recent centuries and are attributable to anthropogenic pressures.

Lagoon hydrodynamics under climate change and increasing human pressure: insights from the Venice Lagoon, Italy

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Coastal zones are transition areas, where erosion and sedimentation processes act simultaneously to reach a dynamic equilibrium. Coastal zones have been the focus of human civilization for centuries, thanks to the ecosystems services they provide. Coastal ecosystems (CEs) such as mangrove forests, salt marshes and seagrass meadows play a fundamental role in protecting coasts from storm surges and flooding and in the mitigation of climate changes, by stocking organic carbon within their sediments. Such capabilities are nowadays fundamental, since the increasing rates of sea level rise (SLR) and the intensification of extreme events (e.g., storm surges), as a consequence of climate changes, threaten the stability of coastal environments. To cope with the effects of changing climate, a number of countries have proposed to build defensive structures which might threaten the already fragile equilibrium of coastal ecosystems. As a matter of fact, the areas covered by CEs have drastically reduced during time, together with the services they provide.

For centuries, the evolution of the Venice Lagoon, the largest brackish water basin in the Mediterranean Sea, has been strongly affected by human interventions, such as the diversion of major rivers in the Renaissance period, the excavation of navigable channels and the construction of jetties at the inlets. More recently, the activation of the Mo.S.E. system, designed to protect the city of Venice and the surrounding urban settlements from flooding, has led to the regulation of tidal fluxes between the sea and the lagoon.

In this study, we propose a mathematical approach to investigate the potential effects of climate changes and increasing anthropogenic pressures on Venice CEs. The two-dimensional hydrodynamic model (WWTM) allowed us to evaluate the possible hydro- and morphodynamic effects of the increasing water levels according to the IPCC projections and, therefore, of the more frequent and prolonged activations of the Mo.S.E. system, comparing open and closed lagoonal configurations for present and future scenarios.

The southern extension of the Tiber delta with the Ostia palaeo lagoon: a record of the Mid and Late Holocene coastal development and human exploitation in the Central Mediterranean

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During the last decades, the northern area of the ancient lagoon of Ostia, and the Tiber delta, have been studied both in a paleoenvironmental and archaeological context. While geologists and micropalaeontologists focused on studying the sea level changes and sedimentary sequences in this highly dynamic deltaic region since the last glacial maximum, archeologists focused primarily on the late Holocene. In particular, great effort has been put in researching the foundation of the Roman city of Ostia Antica in the 7th century BC and its possible relation with salt exploitation in the area, occupied once by the palaeo-lagoon of Ostia. While the northern area of the latter has been investigated, little attention has been put into its southern part, represented by a relatively shallow and only 500-600 m wide water body. Because of its location further from the fast-prograding delta, this area is an excellent location for Holocene paleoenvironmental and sea-level reconstruction studies in the central Tyrrhenian region.

An intensive coring campaign in the southernmost extension of palaeo-lagoon of Ostia enabled the identification of three different stages during the Mid- to Late Holocene (Northgrippian to Megalayan) development of the lagoon: 1) an early lagoon connected to the sea; 2) a closed lagoon with peat deposition; 3) new opening of the lagoon and deposition of shallow marine and lagoonal sediments. Additionally, an inlet connecting the lagoon with the sea has been identified, which functioned alongside with the nearby Archeological Site of Piscina Torta. At the site, thousands of red potsherds have been found, possibly related to the salt production technique known as *briquetage*.

To obtain a clearer idea regarding the nature, age, and anthropogenic use of the three paleoenvironmental stages, the continuous section PT27-2 has been analyzed in detail using geochemical and micropaleontological methods, and the more evident changes in facies have been dated with ^{14}C. This approach allowed us to reconstruct the southern extension of the palaeo-Ostia lagoon before, during and after human occupation of the area.

Land subsidence in the Po Delta: Comacchio case study (Emilia-Romagna region, Northern Italy)

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In the Po Delta area (Northern Italy), rapid subsidence and a large amount of sediments input fostered a complete record of the late transgressive-regressive evolution of the Quaternary when the Po River floodplain reached its maximum extent. Later, slow subsidence processes, progressive sea level rise due to icecap melting and hydrological variations of the Po River have conditioned the development of the territory. Subsidence strongly accelerated with rates up to 8 cm/year due to methane and water pumping carried out in the period 1938-1961, resulting in lowering up to 3-4 meters, with dramatic effects on the rivers and channels outflow to the sea and on the entire ecosystem. Located in the floodplain of the Po river, the phreatic coastal aquifer of Comacchio case study (Emilia-Romagna region) studied in the framework of the PRIMA project RESERVOIR (Sustainable groundwater RESources managEment by integrating eaRth observation deriVed monitoring and flOw modelIng Results) is presented. Brackish lagoon, reclaimed lands with flat topography below the mean sea level and intensive agriculture inland characterize the area. Comacchio area has a complex sediment deposition history and a 700–800 m thick sequence of marine and continental sediments of Early to Middle Pleistocene and Middle Pleistocene-Holocene age that led to a complex hydrogeological setting. The whole coastal area has been affected by land subsidence since the last World War with values that changed significantly over time and space, posing a serious issue to local structures and infrastructures. The loss of land elevation is caused by the superposition of various processes: natural consolidation, peat oxidation, surface loading due to new structures and infrastructures, groundwater withdrawals and hydrocarbon production from deep reservoirs. Disentangling the contribution of each factor to land subsidence is a difficult task due to the lack of specific extensometer stations. In this work, the spatial and temporal evolution of land subsidence is analyzed using historical measurements provided by levelling and interferometric data from ERS-1/2 (1992-2000), RADARSAT (2006-2016) and Sentinel-1 (2016-2021, RESERVOIR project). Finally, land subsidence evolution in space and time is post-processed by several methodologies (PCA, GMA, fastICA) to detect possible relationship with hydrogeological and meteorological data.

Coastal Barriers stratigraphy from the North-West Black Sea document the Black Sea connections to the World Ocean during the Upper Pleistocene

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A 50-m drill (MID) from the Midia coastal barrier (Casimcea Valley, NW Black Sea) was investigated for sediment characteristics (texture, LOI, MS), geochemistry (XRF), ^{18}O isotopes, lipid biomarkers (brGDGT) and paleoecology (meiofauna, pollen) to identify and describe the facies associations. The new data are compared with another regional deep drill (MAM drill, 52 m, on the Mamaia barrier; Caraivan et al., 2012) positioned 8 km south of the Midia barrier. The combined stratigraphies reveal a longshore sequence that captured most of the significant paleoenvironmental changes that affected the western Black Sea coast during the Upper Pleistocene – Holocene; MID core stratigraphy shows a deep-inciding valley cut under the force of major sea-level oscillations.

Here, we present new data on the Black Sea level evolution during the MIS 5 – Holocene (with a focus on MIS5 and MIS3 highstands) and discuss in detail the MIS 3 interval (60-29 ka), which was characterized by fast and intense climatic and eustatic changes that affected the environment and the human living conditions. In the context of the still debated issue of the sea-level reconstruction during MIS3, where part of the direct (sedimentary) evidence of the paleo-coastline does not fit the sea-level reconstructions based on ^{18}O data from deep-sea cores, our results document two marine (transgressive) horizons at depths of 20-25 m and 40-46 m b.s.l. The upper one presents a high salinity and Mediterranean meiofauna corresponding to the last Pleistocene reconnection with the World Ocean. It is still uncertain whether this layer formed during the MIS5a or MIS3 heights, and new numerical ages (OSL) are in progress to compare with preliminary AMS measurements. Considering the two barriers formed on the tectonically stable old Casimcea Plateau (as proved by the morphometric analysis of the river terraces), the present results might elucidate the maximum global sea level recorded globally during the MIS 3 and MIS5a highstands.

Natural and anthropogenic processes in the evolution of low-lying coastal areas at Lipari (Aeolian Islands, Italy) and related vulnerability

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Lipari is the largest and most populated island in the Aeolian Archipelago, a UNESCO site, and a highly frequented touristic destination. However, the waterfront of the Lipari village and other sites in the eastern and northeastern coast of the island are exposed to coastal erosion and flooding, locally enhanced by subsidence effects leading to local sea level rise. Most beaches in this coastal area appear critical, being narrow and sediment-starved. Their possible future disappearance under the impact of climate change and anthropogenic stress should have important near-future implications. Moreover, some of the studied coastal stretches are increasingly threatened by the presence of active canyons offshore, with their heads very close to the coastline, also representing a major geohazard for the local communities due to possible retrogressive erosion and coastal failure occurrence.

In the present study, this setting has been placed in the wider context of the multidecadal evolution of the main beaches, analysed through a multidisciplinary approach, which includes remote sensing techniques (aero-photogrammetry, unmanned aerial vehicle survey, and satellite data), offshore geophysical surveys (high-resolution multibeam bathymetry), and field observations. The results show a variable interaction in space and time between natural and anthropogenic factors in the long- and mid-term shoreline evolution of the studied coastal areas. Among these, changes in sediment supply due to natural or anthropogenic processes, and the construction of human-made structures interfering with the longshore drift are responsible for the main observed coastal changes. An overall precarious but persistent state of equilibrium, with alternating phases of beach accretion and retreat, allowed most of these beach to survive, despite most of them are increasingly threatened by flooding and persistent erosion. As pointed out by our analyses, these processes particularly affect the most populated coastal areas of the island, with important future implications in terms of socio-economic resources and risk assessment, also in the light of future climate changes and related impacts.

Romans did it! From open bay to closed lagune, Stjuža Lagoon, Slovenia

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Stjuža lagoon represents a peculiarity in the otherwise ria coast of Slovenia. It represents a former bay that man has transformed into a lagoon. This transition should be at least several hundred years old, but its exact origins have been lost in the archaeological record. Geologically, the Stjuža is a part of the Late Glacial and Holocene estuary formed during the last marine transgression. As such, it represents one of the most valuable archives documenting a long period of transgression, climate change and human influence in the northern Adriatic, from the last ice age until today. In 2019, four short cores, up to 1.3 m long, were taken from Stjuža Lagoon. They were dated by C14 and subjected to sedimentological, mineralogical and geochemical analysis. The results show that Stjuža was an open bay from the earliest transgression about 9000 years ago to AD 50, where mainly clastic terrigenous sediments were deposited. Around the year 50 AD the Romans built the embankment changing the Stjuža area into a closed lagoon. In the lagoon, biologicaly govern sedimentation prevails and the energy of the environment is much lower. In addition, the Stjuža sediments clearly record the Holocene, Roman and Middle Age warm episodes and interwening cold ones. The Stjuža archive also provides evidence of atmospheric lead pollution since Roman times, with a peak of pollution around 1620 AD.

Geospatial Analysis by Portable OSL of the Expansion of the Plot and Berm Groundwater-Harvesting Agroecosystem, Caesarea, Israel

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Sandy beaches have been prone to growing anthropogenic pressure during the last millenniums that have controlled activation and stabilization of coastal aeolian systems. Apparently only in the Early Islamic period, aeolian sand began to be significantly but intermittently used for agriculture in the form of Plot-and-Berm (P&B) agroecosystems along the Mediterranean coast of Israel.

P&B agroecosystems are agricultural utilization of a high-water table within loose, aeolian sand situated in agricultural hinterlands. Agroecosystems are comprised of a checkerboard array of agricultural plots sunken between 3-10 m high berms. The berm interiors include sand mixed with refuse, overtopped by a dark grey anthrosediment. Similar refuse is used to form a distinct 30-50 cm thick anthrosols within the plots, covering natural aeolian sand, approximately 1-3 m above the groundwater table.

This study is part of a comprehensive geoarchaeological research of the P&B agroecosystems of Israel. The studied agroecosystem, 1 km south of ancient Caesarea, stretches around 2 km along the coast, and its width between the coast to its eastern extent is around 0.5 km. Here, during three excavation seasons, anthrosol-like units were found to comprise substrates of several types of structures upon the berms that were excavated.

Geospatial analysis of the geometries of the plots revealed changes along a west-east transect suggesting an inland oriented expansion of the agroecosystem. Portable OSL (POSL) measurements of bulk sediment samples of berms, plots and excavated structures throughout the Caesarea P&B agroecosystem (Israel) were analyzed using cluster analysis to determine hypothesized spatial expansion stages of the agroecosystem and to chronologically correlate between the structural features of the agroecosystem. Initial finds show that POSL profiles of berms suggest rapid construction in one build-up stage, let alone maintenance of the upper anthrosol while the whole agroecosystem, as the structures were constructed and utilized in several episodes during the Early Islamic and beginning of Crusader period.

Coastal response to early to mid-Holocene sea-level change: a case study from Singapore

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The deceleration of early to mid-Holocene (10 – 7 cal. ka BP) sea-level rise (SLR) played a key role in transforming coastal systems from estuaries to deltas. Palaeoenvironmental reconstruction of coeval coastal evolution provide case studies that can help project the response of modern coastal systems to future SLR. More than 1.3 billion people today live within 100 km of tropical coasts, but few Holocene studies of equatorial delta systems exist.

Here, we investigate the early to mid-Holocene coastal response to decelerating rates of SLR through paleoenvironmental reconstruction of the Kallang River coast in Marina South, Singapore (1.27°N, 103.86°E). We produce a high-resolution, multi-proxy (i.e., sedimentology, stable carbon isotope, XRF elemental ratios) record from sediment core MSBH01B to compare with the latest Holocene sea-level record for Singapore. We identify different coastal response phases through understanding the interplay between accommodation space (A), driven predominantly by SLR and a function of water depth, and sedimentation rate (S) using the A/S theory.

Rapid SLR of up to 15 mm/yr coupled with low sedimentation rates of 2.5 mm/yr led to localised mangrove disappearance at Marina South within ~300 years (9.5 – 9.2 cal. ka BP). Estuarine sediments were deposited from 9.2 – 8.8 cal. ka BP during high but stable SLR of 12 – 15 mm/yr and highest sedimentation rates of 5 mm/yr. Prodelta sediments were deposited from 8.8 – 8.2 cal. ka BP during high but decreasing SLR of 5 – 12 mm/yr and high sedimentation rates of 3 – 5 mm/yr. Delta front sediments were deposited from 8.2 – 7.8 cal. ka BP during low and decreasing SLR of 3 – 5 mm/yr and similar sedimentation rates of ~3 mm/yr. A prograding delta started forming from 7.8 – 7.2 cal. ka BP during lowest but stable SLR of 3 mm/yr and lowest sedimentation rates of 2 – 3 mm/yr. This study may aid predictions of modern coastal response to a variety of future SLR scenarios.

Evolution of coastal environments under inundation scenarios using oceanographic model and remote sensing data

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During the Quaternary period, coastal changes, induced by the variability of climate, sea level and other natural drivers, occurred. In recent times, additional changes produced by urbanization and human activities led to profound coastline modifications. On a larger scale, human activities are also responsible for the global climate change and the associated global sea level rise trend. Quaternary coastal evolution is studied worldwide due to coastal erosion's social and economic impacts at different time and spatial scales.
In the present work, we use a high-resolution projection of future Mediterranean sea level realized at ENEA to evaluate the future risk of inundation. Different study areas of the Mediterranean Sea are investigated considering the recent sea level rise ENEA model MED 16 scenarios as the sea level fluctuations are critical factors affecting the inundation of coastal plains. The modelled sea level, together with the most advanced satellite-derived products for the characterization of the coastal environment, are included in a GIS-based approach that allows to integrate different datasets in order to obtain a reliable understandings of the coastal evolution. Local geomorphological and earth surface processes result in a continuous migration of shoreline which is enhanced or mitigated by geological and anthropogenic factors (subsidence, tectonics, etc.).
Study areas are investigated by using European Ground Motion Service (EMGS) and/or other high-resolution datasets, where available, such as the regional Synthetic Aperture Radar (SAR) or proximal sensing datasets. The coasts of Follonica and Marina Di Campo (Tuscany), Fertilia (Sardinia) and Circeo National Park (Latium) were selected as representative case study areas.
Main outcomes of this study are coastal flooding areas simulated by using the "*bathtub*" approach without considering the morphological effects during the inundation process. The Inundation zone is represented by the water level raised on a coastal DEM, selecting all areas that are below the predicted new water level. The inundation scenarios also include land cover characteristics provided by Corine Land Cover (CLC) High Resolution Level (HRL). Time horizon of 2040, 2070 and 2100 are compared and discussed considering spatial variation of local ground motion due to different geological processes as well as land cover features.

Session 107: More than the sum: fault re-ruptures and cumulative damage during seismic sequences

Completeness magnitude and b-value of Sicily and surrounding region (Italy)

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In recent decades, the scientific community has given greater importance to the Gutenberg-Richter (GR) law (Gutenberg & Richter, 1944). GR is an empirical law that relates the number of events to their magnitude. The parameters of this relationship are the *a*-value and *b*-value, together with the completeness magnitude (*Mc*). The estimating of *b*-value has important scientific fallout for seismo-tectonic characterization (Petruccelli et al., 2021), research to constrain magma storage (Murru et al., 2007) or seismic sequences precursor (Gulia et al., 2018; Gulia and Wiemer, 2019; Lombardi, 2021).

The subject of the research study is Sicily and surrounding region, which is characterized by many seismic-tectonic structures like Tindari Fault System, Gela-Catania fault, onshore fault, and Hyblean-Maltese escarpment and South thyrrenian fault in offshore zone. Furthermore, in Sicily there are various volcanic systems such as the Aeolian Islands, Pantelleria, Etna, Ustica. The seismic sequence that occurred in the last century in the area object study is the one known as the "2002 Palermo earthquake".

The work focuses on the estimation of *Mc* and *b*-value, with various techniques: MAXC (Maximum Curvature) (Wiemer et al., 2000), MBS (Mc by B-value Stability) (Cao and Gao, 2002); and new applications developed by Taroni, 2021.

For the correct estimation of the *b*-value it is necessary to use an appropriate technique and correctly determine the value of *Mc.* The analysis was conducted on the Istituto Nazionale di Geofisica e Vulcanologia seismic catalogue for the period from 2002-2022.

The *b*-value map was compared with the distribution of known seismic sources, the main past seismic sequences, and the volcanic districts present in the studied area.

New empirical relationships relating earthquake induced landslides density and seismological parameters derived from the Italian historical earthquake record

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Earthquakes can trigger secondary coseismic effects related to the ground displacement/deformation and the seismic action connected to the seismic waves-induced ground shaking. These secondary effects include surface faulting, river ponding/diversion, liquefaction and, among all, landslides. They occur almost constantly, regardless of the kinematic characteristics of the seismogenic sources, affecting more or less wide areas according to the seismic energy released. Besides potentially increasing the earthquake damage to the infrastructures immediately after the mainshock, they pose long lasting secondary hazards to the earthquake affected areas, also driving the morphological evolution of the territory.

Earthquake Induced Landslides (EILs) are among the most diffused secondary hazard connected to the tectonic activity, and especially affect young mountain terranes connected to the ongoing tectonic plate dynamics, where the landslides susceptibility is high, due to morphological, geological and structural reasons.

Italy sits on the plate boundary separating the slowly converging Eurasia and Nubia plates, and its mostly mountain territory is characterized by a relatively high seismic hazard, making it highly prone to EILs occurrence.

Building on a revision of the seismic induced natural effects of the CFTI5Med historical seismic catalogue, made within the INGV-UniCH FRASI Project financed by the Ministry of the Environment, we improved the database of historical EILs, collecting new data points, checking the already existing ones and geographically locating them more accurately in a GIS environment. The CFTI improved database now includes >1000 historical EILs, associated to 159 seismic sequences occurred between 117 b.C. and 1997.

We used this database to develop new empirical relationships relating the variation of EILs density with distance from the epicenter as a function of the earthquake magnitude. Using shake maps of historical earthquakes, recently published by the INGV, we also developed a new empirical relationship relating the variation of EILs density with distance as a function of the PGA.

These empirical relationships were used then to relate each landslide belonging to national landslides inventories to segments of the known seismogenic sources (DISS database), that may trigger their activation during future earthquakes, and, using a floating hypocenter approach, to build preliminary EILs scenarios for each potential hypocenter location.

Environmental effects triggered by the 19 September 2022, Michoacan earthquake (Mw 7.6): application of the ESI-07 scale

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On 19 September 2022 a Mw 7.6 earthquake occurred along the Mexican subduction zone in the Michoacán region with an onshore epicenter at a focal depth of 15 km. We document the environmental effects triggered by the earthquake by means of field surveys and remote sensing. Observed primary effects include permanent coastal uplift, while secondary effects include landslides, rock fall, liquefaction, ground cracking, lateral spreading and tsunami waves.

We assign an ESI-07 (Environmental Seismic Intensity) value to each site where an environmental effect has been observed. ESI-07 is an intensity scale based only on effects on the natural environment; intensity values are based on the dimension of each effect: amount of tectonic uplift or subsidence; volume of mobilized material for slope movements; length and width of ground cracks; diameter and height of liquefaction sand boils. We investigate the spatial distribution of earthquake effects and we draw isoseismal lines; we analyze the intensity attenuation with distance, comparing the 2022 Michoacán earthquake to previous events in the same region. Additionally, the comparison of this case study with a dataset of over 150 earthquakes analyzed using the ESI-07 scale shows a good consistency.

One of the challenges in documenting the environmental effects by the Michoacán earthquake is rainfall. Heavy precipitation in the days following the earthquake quickly erased or altered some of the effects, in particular the smaller ones. We argue that a methodological approach complementing a rapid acquisition of data in the field, screening of local news sources and remote data analysis (e.g., satellite images) can partially overcome such limitations. EEEs analysis provide useful information that should not be neglected in seismic hazard assessment.

Surface Rupture and Fault Characteristics Associated with the 2020 Mw 6.6 Masbate Earthquake

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On 18 August 2020, a magnitude (M_W) 6.6 earthquake, whose epicenter was located in Cataingan Bay, struck the island of Masbate. Preliminary investigation and seismological data indicate fault movement consistent with the Philippine Fault. In 2003, Masbate was also struck by a magnitude (M_s) 6.2 earthquake. Separated by 17 years, Masbate was struck by two M>6 earthquakes that ruptured the same segment of the Philippine Fault. The occurrence of these two strong earthquakes with very close proximity in both space and time leads to the opportunity to understand the overall seismic and slip behavior of the Masbate segment of the Philippine Fault. This study aims to determine how the fault slip associated with the 2020 earthquake was accommodated along the Masbate segment through deformation and seismicity pattern analysis. The study also aims to determine how the 2003 and 2020 earthquakes interacted, in terms of earthquake-triggering effect and slip distribution.

The 2020 M_W 6.6 Masbate earthquake produced an approximately 23-km long surface rupture onshore. Generally straight, the surface rupture exhibits continuous surface breaks, distinct shear faults, right-stepping tensional cracks, and mole track structures, which together indicate left-lateral strike-slip movement. The left-lateral displacements reach up to ~97 cm. Secondary ruptures allude to a wider and distributed deformation near the epicenter InSAR observation, supported by field investigation, indicates that post-seismic slip occurred along the rupture zone of the 2020 M_W 6.6 earthquake. The analysis of marine geophysical data revealed the possible offshore continuation of the fault rupture. Coulomb stress model suggests that the 2003 earthquake increased stress on the location of the 2020 earthquake, however, the surface rupture of the 2020 earthquake was not confined by stress decrease but rather overlapped with the 2003 surface rupture for ~20 km. Slip distributions of both surface ruptures appear complementary to each other. Both the 2003 and the 2020 earthquakes involve foreshock activity and post-seismic slip. The results of this study can provide insights into the rupture dynamics of the fault. The fault rupture history offers useful data about its likely future behavior, allowing for earthquake hazard predictions and risk mitigation.

Not Again! Short Time Intervals Between Surface Re-rupture of a Fault or Fault Segment

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The energy released during earthquakes results from slip on fault planes. The concept of the earthquake cycle developed by Reid following the 1906 San Francisco earthquake–the accumulation of stress, it's release as slip on a fault, it's re-accumulation and re-release as fault rupture–provides us with fault recurrence intervals. These are a basic component of seismic source characterization. Depending on fault type, location in a regional stress field, and slip rate, recurrence intervals for most crustal faults or fault sections are typically in the hundreds of years to millennia.

Some recent seismic sequences, however, (2016 Kumamoto, Japan; 2016 Central Italy) unequivocally document that the same fault section can undergo repeated surface rupture in a short time interval (hours to months). This process has not been adequately documented so far, and it may have an impact on various types of seismic hazard assessment.

Here we describe a dataset of repeated historical surface ruptures along individual faults. We have collected a total of 34 cases of historical re-rupture on 25 fault segments globally. We investigate the kinematics and spatial pattern (length, displacement) of surface faulting for each rupture and the time interval (typically a few to many tens of years) between events. We develop two numerical indicators based on surface rupture lengths and the degree of overlapping, and develop a model comprised of four classes of re-rupture: identical, partial overlap, complete overlap, and rupture along conjugate faults. Finally, we discuss the implications of repeated short-term re-ruptures on empirical scaling relations and implications for paleoseismic interpretations.

The role in hazard analysis of short re-rupture times for any of the rupture classes noted is unclear although it has not been a significant issue in modeling strong ground motion hazard at present. However, re-rupture in the short-term may be an important consideration for fault displacement hazard analysis as it affects pipelines and other critical infrastructure crossing active faults.

Session 108: Equitable and ethical knowledge production in Quaternary Science

Parachute science in palaeoecology: learning from past praxis

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Palaeoenvironmental science has gained real prominence in discourses around climate and conservation futures, but the discipline has failed to question how our global-facing science has perpetuated colonial forms of knowledge extraction and production.

Palaeoecology, in particular, has produced remarkable insights into long-term landscape evolution and human-environment interactions, as well as providing impressive datasets that have fed into valuable global climate and biodiversity assessments – but the discipline continues to overlook the ways in which its colonial legacy and biases can ignore, erase, undermine and disadvantage communities in areas where research is conducted. Frequently, these communities are 'told the story' of their own people, and their responses and contributions to environmental and climatic change, often without involving or considering their ideas, knowledges or priorities. Furthermore, such studies risk drawing conclusions from an incomplete understanding of past environmental processes and trends, lacking in local knowledge and context, and potentially resulting in biased and/or inaccurate assessments of ecological baselines.

Awareness of these issues is growing across the palaeoecological community, and efforts to promote ethical and equitable practice are increasing, but there remains a lack of formalised scholarship in the field relative to other sub-disciplines of environmental and earth science. Here, we present results of a systematic and quantitative literature review of the extractive, neocolonial practice of 'parachute science' in palaeoecology – a process that sees researchers from the Global North undertake fieldwork in post-colonial and/or indigenous nations without meaningful engagement with or benefit for local communities. We developed a Python-based scraping tool which allowed us to extract a number of metadata variables associated with publications contained in Scopus keyword search results. After manual data validation, we produced a final dataset containing 7654 papers for quantitative analysis.

In addition to revealing how trends and patterns in palaeoecological parachute science have evolved in the published literature (1963-2022), we aim to highlight where and how equitable and ethical practice of scientific knowledge (co-)production is and could be taking place. We aim for our work to contribute to an important and positive conversation about a more equitable future for palaeoecology and Quaternary science more broadly.

Developing participatory palaeoecology approaches using 3D pollen models

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1. *University of York*

Palaeoecology plays a crucial role in ecology, providing unique insights into ecosystems' long-term histories. Palaeoecologists and our methods are not alone in being able to shed light on past environmental change, however. Indeed, bringing together a wider range of perspectives and worldviews could yield a more holistic – and, by extension, complete – understanding of an ecosystem's past. This talk introduces two approaches which are being developed to explore new ways of uncovering long histories of ecosystem change alongside a wider range of public audiences. Both use 3D pollen data and tactile models to facilitate two-way communication and engagement between user communities and researchers.

The first approach aims to develop and deliver accessible training in pollen identification techniques for citizen scientist 'para-palaeoecologists'. Resources from the 3D Pollen Project, including physical and virtual models, super-resolution cross-sections and linked light micrographs, are combined to provide an intuitive and engaging introduction to the principles of pollen identification. Integrated with the eSlide virtual microscope software, these resources provide significantly improved learning and opportunities for practice compared to traditional teaching methods. By pioneering, evaluating and refining new pedagogical approaches, this project will lay the groundwork for wider citizen science involvement in palaeoecology, with implications for other teaching and learning settings.

The second approach recognises that conventional ecological interpretations of proxy data provide only a partial (and biased) view of ecosystems' histories. Combining palaeoecology, ecology and archaeology to study past land use is not uncommon, but including traditional ecological knowledge (TEK) and Indigenous voices/worldviews is very rare – both a blind spot and a source of inequity in our research. We are therefore building dialogues with Kaingang communities in southern Brazil about the region's palaeoecology and archaeology. These conversations are not only about sharing findings with people on whose land and ancestors the research focuses, but also pave the way for further collaborative, co-designed research which links TEK and scientific knowledge of past and future environments. This more 'two-eyed seeing', 'participatory palaeoecology' approach could yield stronger insights into past environmental change through more just and equitable processes of knowledge generation.

Nun cho ga: the story of a mummified baby woolly mammoth and how it is redefining our approach to Quaternary science

Mr. Jeffrey Bond [1]***, Ms. Debbie Nagano*** [2]***, Dr. Brent Ward*** [3]***, Ms. Elizabeth Hall*** [4]***, Dr. Grant Zazula*** [4]***, Mr. Derek Cronmiller*** [1]***, Dr. Duane Froese*** [5]***, Mr. Scott Cocker*** [5]***, Dr. John Southon*** [6]***, Dr. Britta J.L. Jensen*** [5]***, Prof. Michel Lamothe*** [7]

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A nearly complete, mummified baby woolly mammoth (*Mammuthus primigenius*) was discovered in the Klondike region of Yukon, Canada in the summer of 2022. This is the best preserved North American mammoth yet discovered, owing to its rapid burial and permafrost preservation, and is of similar quality to the exceptional specimens from Siberia such as Lyuba and Dima. Placer gold miners made the discovery while mechanically stripping frozen Pleistocene loessal sediments that overlies the valley-bottom, gold-bearing gravel on Eureka Creek. The discovery and rapid recovery of Nun cho ga was made possible because of the strong relationship between Yukon government scientists and the mining industry. This collaboration has also allowed a detailed record of the stratigraphic, paleoecological and geological setting of the site.

The mammoth was appropriately named by the Tr'ondëk Hwëch'in First Nation, Nun cho ga, meaning 'Big animal baby' in the Hän language. In the days following the discovery, the Tr'ondëk Hwëch'in First Nation led a series of ceremonies to honour Nun cho ga's arrival and has subsequently assumed a guardianship role of this mammoth.

Central to our experience with Nun cho ga has been the profound manner in which it brought together a diversity of people including Indigenous leaders and elders, gold miners, scientists, and politicians. This union has broadened the meaning of the discovery, and importantly, introduced Indigenous spirituality to this palaeontological discovery. With that, Nun cho ga has the potential to contribute to reconciliation and a new inclusive approach to effective collaboration of natural history resources.

This talk will detail the discovery of Nun cho ga, our current understanding of the mammoth, the landscape it inhabited, and its significance. We will also describe the mechanism of preservation, and the additional information contained in its geological setting. The ongoing and potential research is substantial, and we will outline our plan and approach to ensure this discovery leaves a legacy of understanding. Most importantly, we will convey how a scientific discovery, when viewed through an Indigenous cultural lens, can reach beyond science and provide an opportunity for community healing.

Decolonising archaeology in Iraq

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Iraq has vast quantities of well-known and world-leading heritage as well as less well-known but equally significant sites. Each year it hosts many international teams who are keen to work on these sites. In this presentation, we discuss the difficulties with the present situation and also offer some solutions. Key to this process is the proper inclusion of Iraqi researchers (including the many young researchers currently being trained) in both research and publication. Publications should also be easily available in Arabic, and time and resource should be factored into projects to build capacity and engage the public within the country. There are also real threats to the preservation and conservation of sites and artefacts that can be tackled by a partnership between local international teams of researchers.

Session 109: Animals, environments & humans: diverse perspectives from the Quaternary

After the Acheulean: the lithic-fauna nexus in the Levant and beyond

Prof. Ran Barkai [1]

1. *Tel-Aviv University*

Significant cultural and biological transformations took shape in the course of the process of changes from Acheulean to post-Acheulean human adaptations in the Levant and beyond. In this talk I will put an emphasis on the lithic-fauna nexus, in an attempt to correlate between faunal turnovers/transformations and possible related technological preferences. I will focus on the dependency of Paleolithic human groups on large game and the significant relations between hunters and their prey. I will suggest that human interactions with animals were not only practical and economic, but based on ontological and cosmological conceptions. Thus, changes in the availability of major game animals might have necessitate a significant modification in human mode of adaptation, which is not only practically oriented. Furthermore, several behavioral transformations characterizing the Acheulean and post Acheulean continuum will be viewed in light of the evidence for the decline in game size during the Pleistocene. This talk will attempt at presenting a new model for reconstructing changes in human adaptation during Middle Pleistocene times in the Levant and beyond.

Geological and paleontological insights on a new Late Pleistocene fossil-bearing locality at Olduvai Gorge (Tanzania)

Ms. Beatrice Azzarà [1], ***Prof. Marco Cherin*** [1], ***Prof. Giovanni Boschian*** [2], ***Mr. Jackson Kimambo*** [3], ***Prof. Fidelis Masao*** [4], ***Dr. Fabio Bona*** [5], ***Dr. Omar Cirilli*** [6], ***Dr. Alessio Di Roberto*** [7], ***Dr. Maximiliano Fastelli*** [1], ***Dr. Elia Pandolfi Balbi*** [1], ***Dr. Azzurra Zucchini*** [1], ***Prof. Stanley Ambrose*** [8], ***Prof. Giorgio Manzi*** [9]

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The rocks that crop out in the world-famous Olduvai Gorge (Tanzania) span the last 2 Ma and are very rich in paleontological and archeological remains, offering a clear glimpse of human evolution in the context of East African Quaternary environmental changes. However, research in Olduvai has been focused much more on the lower part of the succession (Beds I-IV), certainly richer in paleoanthropological evidence, and less on the upper part (Masek, Ndutu, and Naisiusiu Beds).

This study reports on a new fossil-bearing locality at Geolocality 83, near the 5th Fault of the Main Gorge, discovered by the THOR (Tanzania Human Origins Research) team within deposits referable to the Ndutu-Naisiusiu Beds. The first paleontological interpretation of the assemblage and preliminary geological data to reconstruct the depositional paleoenvironment are provided.

The rich and well-preserved vertebrate assemblage from Geolocality 83 is dated to 34.6-38.8 cal ka by AMS radiocarbon analysis of three ostrich eggshells. The assemblage includes

Crocodylus sp., Agaminae indet., *Struthio* sp., *Hyaena hyaena*, *Lycaon pictus*, *Canis lupaster*, *Vulpes* sp., *Caracal caracal*, *Acinonyx jubatus*, *Panthera pardus*, *Equus quagga*, *Taurotragus oryx*, *Syncerus antiquus*, *Nanger granti*, Bovidae indet., *Phacochoerus africanus*, *Pedetes* sp., and *Gerbilliscus robustus*. Hyena coprolites are also present, as well as common hyena-made modifications on vertebrate bones. Except for a few taxa (e.g., the extinct *S. antiquus*), the assemblage is largely composed of species that can be found in the present-day Serengeti savannah. Taxa such as the crocodile and especially fox suggest that the Olduvai paleoenvironment might have been at least partially different from today. Analysis of the stratigraphy and depositional environments highlights that the assemblage is the result of different burial events of which the main one is to be attributed to a hyperconcentrated flow, which is probably among the most common sedimentary processes underlying the formation of the Ndutu and Naisiusiu Beds. Stratigraphic, lithological, and sedimentological differences between the studied outcrop and the type sections of the Ndutu and Naisiusiu Beds suggest that the definition, age, and genesis of these stratigraphic units need to be revised.

Biochronology and palaeoecology of Kromdraai Unit P, South Africa, based on the fossil Bovidae

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The Kromdraai palaeontological site, located in the Cradle of Humankind (Gauteng Province, South Africa), has produced a diverse and abundant Plio-Pleistocene faunal assemblage, including key hominin specimens like the holotype of *Paranthropus robustus*. However, despite its richness and importance, the large mammal assemblage remains understudied, especially regarding the Bovidae family. Here, we provide the first taxonomic study of the newly excavated hominin-bearing deposit of Kromdraai Unit P. The bovid assemblage is composed by old Pliocene species (*Gazella gracilior*, *Makapania broomi*), a new species of buffalo species (*Syncerus* n. sp.), as well as younger Quaternary taxa (*Tragelaphus strepsiceros*, *Oreotragus oreotragus*, *Raphicerus campestris*, *Connochaetes gnou*, *Damaliscus lunatus*). Overall, bovids indicate a grassland dominated environment for the Unit P. By comparing with other Plio-Pleistocene South African sites, it is clear that *Australopithecus* is associated with woodland and closed-wet environment adapted taxa while *Homo* is found along bovid species that are adapted to open and dry environments. In contrast, the assemblages associated with *Paranthropus* show a variability of environmental adaptation among the bovids. Based on biochronological evidence, we show that the Kromdraai Unit P accumulated between 2.9 and 1.8 Ma, with a good probability to be older than 2.3 Ma.

Pleistocene bone technology from mammoth long bone (Tocuila, MEXICO)

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Research on the eastern shore of the Basin of Mexico, specifically in the ancient lacustrine plain of Tocuila, Municipality of Texcoco, State of Mexico, has made it possible to document the existence of twenty locations with bone remains of *Mammuthus columbi.* This work has identified the existence of an archaeo-paleontological complex covering an area of about 60 ha. Taphonomic analysis was undertaken with more than 1,300 bone remains recovered within a paleochannel filled with mud by a succession of various mudflows. Numerous fragments were identified that presumably were modified by anthropic action. According to C14 dating, these remains that came from stratigraphic units SU1 and SU5 would have accumulated at various times over three millennia from 12 and 15 thousand years before the present. The bone remains were analyzed individually to establish the taphonomic processes and identify the agents that would have influenced their condition, providing additional detail on the characteristics of the deposit formation process.
Three modification types were identified. The first consisted of simple cut marks on bone. The second was constituted by a large set of elements that morphologically suggest their probable use as fortuitous tools, presumably associated with butchery activities at the site. Both types are still subject to microscope studies to assess confirmation of human modification and use. The third type of culturally modified bones corresponds to the process of reducing long bones that were emaciated in quarries, spaces where there was previously slaughtered and butchered. A little less than fifty fragments have been recovered from these, which when analyzed as a whole reveal the existence of a reduction sequence that qualifies as bone technology. This technology is fundamentally oriented towards deriving raw material from the thick cortical structure of the large diaphysis and its eventual transformation into functional elements by its cutting edges. Here we present the characteristics of the third assembly type and the reduction sequence of the Pleistocene bone technology specialized in long bones of *Mammuthus columbi* documented in the Tocuila site.

Homo erectus, a successful hunter, catcher, or scavenger? An agent-based model about early hominin strategies to acquire meat in grasslands

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The reasons for turning points in the history of early hominins, for instance the first dispersal of *Homo erectus* out of Africa, are often assumed to be related to environmental changes and/or access to new resources. It has been proposed that H. *erectus* used spreading grasslands with their large herds of herbivores as a corridor to disperse into Eurasia after 2.5 million years ago. How these hominins gained access to meat obtained from large animals is still under debate.

We used an agent-based model to test the effects of different proposed strategies to acquire meat. The agents in the model represent hominin foragers exploiting plants and animals to cover their daily energy demand. The model allows simulating different subsistence strategies by granting or restricting the foragers access to certain types of resources. On the basic level all foragers have access to plants, but some can additionally use strategies to acquire meat by catching smaller animals or hunting large herbivores. Furthermore, the model permits to adjust how they interact with the resources by forcing them to target certain resources, i.e., the group needs to cover its energy demand to a certain percentage by hunting.

We tested several subsistence scenarios derived from recent hunter-gatherer societies, which correspond to subsistence strategies proposed for H. erectus. The scenarios differ in the percentage of meat in the diet and the strategies applied to obtain it. To monitor the effect on the group we observed the resulting mobility patterns, the energetic return during foraging as well as the diet composition. The model reflects that H. *erectus* had several options to cover his demand in this ecosystem depending on how they exploited meat as a food source. We will present some of our results and discuss future applications of the model.

Middle Palaeolithic Avian Remains from Tabun Cave (Israel): A Palaeoenvironmental Reconstruction

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Mount Carmel plays an important role in the movement of Middle Palaeolithic (MP) humans. The archaeological record establishes early dispersal waves of anatomically modern humans expanding out of Africa, as well as insights into potential episodes of interaction between the different hominin populations that inhabited the region. Taxonomic and taphonomic analyses of avian remains recovered from the MP layers at Tabun Cave (Mount Carmel, Israel) have provided a window through which we can examine the environment and climate in which these interactions took place.

Forty-seven species of bird were identified in 27 stratified samples from the ca. 6-m-thick archaeological deposit that constitutes the later part of the MP at Tabun Cave. These included game birds, diurnal and nocturnal raptors, waterbirds, pigeons, and small songbirds. Rock doves (Columba livia) accounted for the greater part of the assemblage in both the middle (Layer C) and later (Layer B) MP sequence. However, while some human agency was suggested by thermal traces on some bones and a significantly higher occurrence of Rock Dove remains in Layer C, data collected from Layer B reflected a wholly natural accumulation created by natural death and raptor agency. This allows us to compare the species and habitats reflected in two different modes of accumulation. Small passerines and raptors in Layer B represent the inhabitants of a cave rarely visited by humans, giving us an unbiased snapshot of the species active directly around the site. Layer C on the other hand indicates a wider catchment area, including species purposefully introduced to the cave from further afield such as water birds from the wetlands of the Mediterranean coastal plain below.

Habitat fidelity information and temperature- and rainfall preferences of each identified species were extracted from current-day distribution data and analysed to create a reconstruction of the surrounding palaeoenvironment and climate conditions throughout the MP sequence. This information was used to place Tabun in the context of other Israeli MP sites with identified bird assemblages, including nearby Kebara Cave, and produce a portrait of the Middle Palaeolithic Carmel environment where our human ancestors met and coexisted.

Faunal and Human Evolution in the Middle to Late Pleistocene of Sudan

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Despite the existence of the Nile River in some form since the early Oligocene, very little is known about its potential role as an ecological refugium or faunal and cultural dispersal route during this long timeframe. Sudan covers a large portion of the Nile Basin, yet its vertebrate fossil record remains little explored. Since 2018 our team has conducted yearly fieldwork in Sudan with the aim of exploring faunal, archaeological, and environmental evolution during the Middle to Late Pleistocene of the Nile Basin. Following previous work by Abbate et al. along the middle Atbara River in the early 2000s, our renewed investigations have resulted in the discovery of many new sites, the recovery of a diverse faunal assemblage that includes hominins and lithics, and a new high-density OSL and 14C geochronology spanning ~250 ka to ~15 ka.

The new fossil collections comprise over 700 specimens representing over 30 species. A large number of extant taxa provide the opportunity to examine sub-specific (morphoclinal) variations between Sahelian, northern African, and eastern African forms, and to reconcile the fossil record with extant phylogeography. Extinct forms include *Elephas jolensis*, *Kolpochoerus majus*, *Syncerus antiquus,* and a hipparionine equid. Other finds include the first record of a macaque (*Macaca*) in sub-Saharan Africa, a possible northern white rhinoceros (*Ceratotherium simum cottoni*), small *Hippopotamus* and warthogs *(Phacochoerus*). The bovids indicate standing wetland habitats in what is today a region with highly seasonal rainfall and sparse vegetation. Hominins are represented by robust cranial and postcranial remains attributable to Middle Pleistocene *Homo*, and are also represented by a well-preserved Acheulean lithic assemblage. At ~160-80 ka, the hominin and Acheulean remains could be contemporaneous with early *Homo sapiens* and Middle Stone Age assemblages in other parts of the continent, suggesting the late persistence of archaic hominins and Early Stone Age culture in the Middle Atbara area. The Middle Atbara project is opening up a new regional window onto Pleistocene biogeography and the emergence of modern African ecosystems. New paleontological surveys planned for winter 2023 will target the Blue and White Nile rivers, and the initial results will also be presented here.

Multi-aspect perspectives on the Pleistocene fauna of peninsular India including current issues and future directions

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This paper reviews the known and some new occurrences of fossil vertebrates in Pleistocene contexts across central and southern India. Several hundred occurrences have been reported since colonial times, all of which primarily derive from fluvial contexts. These sites include Pleistocene mammals of various sizes including hominin material in central India and possible cu-marked bones from southern India. A historical review indicates research bias in specific river valleys where vertebrate fossils are generally common and occur in diverse sedimentary contexts including layers of loose or consolidated sand, silt and gravel. The Son and Narmada river valleys have yielded the highest amount of fossil material while other lesser known areas have yielded find spots or low density occurrences. The most abundant elements preserved are represented by teeth and mandible/maxilla fragments while rich bone beds or fossil clusters are generally sparse (with some rare exceptions). Current issues in Indian palaeontology are also discussed: a) how to fill the geographic gaps; b) confronting the chronological gaps; c) possible impacts of the Toba super-eruption; d) factors of extinction of specific species and co-evolution with hominins; and e) explanations for missing evidence such as hominin fossils and butchery assemblages. Finally, the paper also touches upon broad observations in relation to elemental preservation, taphonomy and potential taxonomic connections with the Pleistocene fauna of southeastern Asia. While understanding the Pleistocene palaeontological records of India is not without its challenges, the subject holds great potential for further multidisciplinary research at various levels.

Animal exploitation at the dawn of Neolithic lifeways in the foothills of the Zagros Mountains: new evidence from Chogha Golan (Iran)

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Chogha Golan is an Aceramic Neolithic tell site, located in the foothill of the Zagros Mountains (modern Ilam Province, Iran). Archaeological excavations were carried out by the Tübingen-Iranian Stone Age Research Project team between 2009 and 2010. These excavations revealed an eight-meter stratigraphic sequence, which consists of 11 archaeological horizons, mostly defined and separated by plaster floors and architectural features. Ranging from ca. 11,700 to 9,600 cal. BP, the zooarchaeological record from Chogha Golan is key to understand human-environment interactions and the socioeconomic transformations that took place at the onset of Neolithic lifeways at the eastern part of the Fertile Crescent.

Here, we present the first comprehensive analysis of the faunal remains recovered from the oldest archaeological horizon (AH 11) of Chogha Golan, in order to provide new information about the dietary breadth and animal exploitation behavior of one of the earliest sedentary communities in the region. The ungulate assemblage is mostly dominated by gazelle and sheep/goat, followed by pig and indeterminate large- and/or very large-bodied ungulates, but to a much lesser extent. Small game taxa, including both slow-moving or easy-to-catch game (tortoises) and fast-moving or difficult-to-catch animals (predominantly birds, but also fish), were frequently exploited by humans at the site. Although the carnivore component is relatively insignificant, we also documented a few red fox, wild cat and Eurasian lynx remains in our assemblage. Overall, our results suggest that the inhabitants of Chogha Golan ca. 11,700 cal. BP had a broad diet and exploited a great variety of animal resources and ecological niches. According to the diet breadth model of optimal foraging theory, diverse diets may reflect resource intensification or depletion as a result of increased hunting pressure, population growth and/or a decrease in mobility. We propose that human population density and mobility played a crucial role in shaping human-animal relationships at the dawn of Neolithic lifeways, prior to the adoption of plant cultivation and animal husbandry in the foothills of the Zagros Mountains.

Nonmarine Ostracoda as proxies in geoarchaeology

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Ostracods are small crustaceans, mostly 0.5–2 mm in length, living in almost all types of aquatic habitats, both natural and man-made. Their calcitic carapaces have a high fossilization potential and allow the identification of species and even ontogenetic stages. Due to their small size, only small volumes of sediment are needed for analyses. Species-specific tolerances and preferences allow detailed palaeoenvironmental reconstructions, and typical methods of their applications include palaeoecological analysis of associations based on ecological information, as well as taphonomy, morphometric variability, and stable isotope and chemistry analyses of their valves.

In contrast to many other microfossil groups, ostracods also occur widespread and with high species richness in fresh water, and especially the palaeoenvironmental and palaeoclimatic information from ostracods has therefore been of interest in nonmarine geoarchaeological studies. Other archaeological research questions for nonmarine ostracods are, e.g., water availability and quality, land use and other anthropogenic impacts, and the provenance of materials and commercial networks. Examples include studies of Neolithic sites, where climatic changes and changes in human living strategies can be reconstructed, or reconstructions of environmental histories of areas with human occupation, and analyses of the environmental suitability of areas for human settlements. At more recent sites, climatic changes effecting land and water use, e.g., Mayan swidden and wetland field agriculture, have been interpreted using ostracod proxies, as well as human impacts on the environment, reflected by, e.g., soil erosion or aridification. Land use may be detected by ostracod analysis through eutrophication events, but mostly indirectly seen by deforestation and connected higher erosion rates and thus discharge fluctuations in streams or into lakes. Canals, dams, and other water works can be detected through ostracod analysis, and such structures' usage could be reconstructed, potentially even with a seasonal chronological resolution.

An overview of geoarchaeological studies, which all 107 in some way used nonmarine ostracods, promotes ostracod-proxies for various (geo-)archaeological research questions. At the same time, it displays the sparsity of detailed nonmarine ostracod studies at archaeological sites, which, regarding the state of research and development of new and better ostracod proxies, may further increase in the coming years.

Mollusc assemblages from the Krapina Neandertal site, Croatia (130,000 ya)

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There is emerging evidence testifying to diversity of hominin food resources during the Middle and Late Pleistocene. Recent studies point to the previously ignored importance of other (smaller) protein resources such as various species of edible arthropods and molluscs. Although thoroughly studied at the Holocene sites, mollusc assemblages present at Pleistocene hominin sites have not yet been systematically analyzed to understand its accumulation agency, to test whether they have been intentionally procured, and whether they have been incorporated into hominin diet. Here, we explore the taphonomy and accumulation agents of the mollusc remains from the Krapina Neandertal site, excavated from 1899 to 1905, and dated to 130,000 BP. We also revise the specimens taxonomically. Two classes of invertebrates were preserved and collected in the original excavations from the Krapina site: Bivalvia (1 species) and Gastropoda (7 terrestrial and 2 freshwater species). The revised total NISP is 63. Three specimens are marked with their layer provenience: 613.1 Monacha sp. (layer 8), 615.1 Holandriana holandrii (Layer 4-5, just following the layer with the highest content of Neandertal specimens), and 616 Holandriana holandrii (Layer 1, stratigraphically the oldest). All specimens are very well preserved, with 46 specimens (73%) that are complete or more than 90% complete. Majority of the specimens show black staining (59%), following with small holes (29%), irregular surface depression (25%), limonite staining (21%), and possible small animal tooth marks (18%). Helix pomatia specimens have the most interesting surface traces, including irregular surface depressions and small black linear traces on the shell, while several Campylaea illyrica specimens have traces of small animal predation. The taphonomic analysis points to possible Neandertal collection of the Helix pomatia and at least one specimen of Holandriana holandrii.

Investigating possible links between Holocene environmental changes and cultural transitions across India

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From the early Holocene onwards, the Indian Subcontinent has accommodated a range of diverse human cultures and associated ecological adaptations and lifestyles. From about 10 Ka onwards, the Subcontinent has witnessed the development of later Mesolithic hunter-gatherers and their subsequent regional transitions to pastoralist (Neolithic) and agricultural (Chalcolithic) lifeways. Detailed evidence of Holocene environments indicates fluctuating environmental circumstances, with many cooling periods occurring at ~1500 ± 500-year intervals. These climatic shifts appear to be linked to surface ocean circulations in the subpolar and subtropical regions. These changing climatic patterns including the development of a geographically variable monsoon throughout the Holocene directly impacted these various cultures including the Harappans and their contemporaries as well as younger Historical and Medieval empires across India, at various levels. In some regions, environmental changes led to uneven cultural transitions, geographic migrations, and the development of regionally-distinct material cultures once sedentary life-ways became established. This paper attempts to present a review broadly correlating general monsoon patterns throughout the Holocene period of India with regional cultural dynamics. The temporal variation of human habitation and respective adaptive responses suggest broad linkages to the varying climatic and physiographic features at a regional scale. In some regions, environmental changes led to uneven cultural transitions, geographic migrations, and the development of regionally-distinct material cultures. Learning how this shaped human ecodynamics in the past can help us expand our understanding of human history and implement lessons for the present as well as the future.

New record of Late Pleistocene fossil assemblage from Bandung Basin, West Java, Indonesia: a preliminary date and biostratigraphic significance

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The island of Java emerged above sea level only about two million years ago. Considering its short geological age since becoming a fully terrestrial environment, Java has one of the richest and most diverse fossil faunal sequences in the world. Paleontological records include vertebrate and hominin fossils provide evidence of at least two faunal turnovers throughout the island colonization. The first turnover was from *Sinomastodon – Merycopotamus* fauna into *Stegodon – Homo erectus* fauna in the Early Pleistocene. The second turnover into *Elephas – Homo sapiens* fauna, also known as modern fauna, occurred approximately during the Middle and Late Pleistocene boundary. While *Stegodon – Homo erectus* fauna are widely distributed and well-documented throughout the island, the evidence for Late Pleistocene *Elephas – Homo sapiens* fauna are mostly restricted in cave sediments, while open landscape localities have rarely been reported due to the scarcity of data.

Here, we report the fossil assemblage discovered in the Saguling Reservoir, first reported in late 2021. On the basis of our survey and test excavation, five mammal taxa: *Bos* cf. javanicus, *Bubalus bubalis, Axis axis, Rusa* cf. *unicolor* and *Elephas* sp. are taxonomically identified. The fossil localities comprise fluvial sediments, heavily influenced by volcanic activity. A preliminary age based on ^{14}C dating of older than 50 kya for the fauna has been determined based on Carbon dating of a charcoal fragment contained in the pyroclastic flow overlying the fossil layer. OSL dating on the fossil layer and volcanostratigraphy of the alternate pyroclastic flow and fall layer are currently underway. However, these preliminary data indicate the oldest date for an open landscape site on Java yet recorded, preceding most of the modern fauna of Java

Multiproxy analysis of endangered Yak (Bos mutus) dung from Indian Himalaya: Implications for paleoherbivory and paleoecology

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The study reports the micro- and macrobotanical remains on wild Yak dung, providing evidence for understanding the diet, habitat, and ecology of extant and extinct megaherbivores. Grasses are the primary diet of the yak as indicated by the abundance of grass pollen and phytoliths. Other associated non-arboreal and arboreal taxa namely, Cyperacaeae, Rosaceae, Amaranthaceae, *Artemisia*, *Prunus*, and *Rhododendron* are also important dietary plants for their living. The observation of plant macrobotanical remains especially the vegetative part and seeds of the grasses and Cyperaceae are also in agreement with the palynodata. The documented micro- and macrobotanical data are indicative of both Alpine meadow and steppe vegetation under cold and dry climate which exactly reflected the current vegetation composition and climate in the region. The recovery of *Botryococcus*, *Arcella*, and diatom was observed in trace amounts in the palynoassemblage which would have been incorporated in the dung through the ingestion of water and are indicative of the presence of a perennial water system in the region. Energy dispersive spectroscopy analysis marked that the elements contained in dung samples have variations in relation to the summer and winter, which might be due to the availability of the food plants and vegetation. This generated multiproxy data serves as strong supplementary data for modern pollen and vegetation relationships based on surface soil samples in the region. The recorded multiproxy data could also be useful to interpret the relationship between the coprolites of herbivorous fauna and the palaeodietary, the palaeoecology in the region, and to correlate with other megaherbivores in a global context.

Bear coprolites? Preliminary study of the coprolites from the Juan Labranz Cave (Cuenca, Spain)

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The study of coprolites can provide valuable information about both the producers and the environment in which they lived. The value of coprolites as an indirect record of a species increases in the absence of associated skeletal remains. However, how reliable are the identifications of the producers based solely on this type of remains? Here we present the results after studying 34 coprolites collected *in-situ* in Quaternary sediments of Juan Labranz Cave, a karst cavity in Cuenca (Spain) developed in dolomites located at the boundary between the Iberian Mountain Range and the Tertiary Tagus Basin, in the Jucar River valley. Morphometric studies indicate that most of the coprolites were produced by spotted hyena, but there are two outliers with atypical morphologies exceeding the size of any hyena droppings. According to their width, it is observed that they fall within the typical size of the faeces of modern Iberian brown bears after they have scavenged. Comparing the internal content of the coprolites through a micro-CT scanner, it can be seen that whereas most of the bone fragments assigned to hyenas are smaller and rounded, the two atypical specimens contained numerous fragments of sharp edges, indicating carrion consumption and hardly no digestion of the bones. Although the presence of bears in the Juan Labranz cave was already known because of the bear beds, claw marks and skeletal remains, the study of these two coprolites provides valuable information that can help identify bear coprolites in sites where there is no other evidence indicating the presence of these animals. Furthermore, it broadens our knowledge of these traces, which are very common in Quaternary and older terrestrial deposits.

Carnivores of the Epivillafranchian biochron: contributions from the Sierra de Atapuerca

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Two deposits in the Sierra de Atapuerca include layers whose chronological contexts indicate age positions of around one million years. The first is level TE9c of the Sima del Elefante site, dated to about 1.2 Ma and representing one of the oldest sites with evidence of human occupation in Western Europe. The second deposits are the basal layers of the Trinchera Dolina (TD3-4 and TD5) site, with ages ranging between 1.1 Ma and 0,9 Ma. The 18th International Senckenberg Conference held in Weimar, Germany (2004) saw the proposal of a new Early Pleistocene biochron: the Epivillafranchian. While this term previously had been proposed by Bourdier in 1961 and some authors later considered it, the main catalyst for its establishment came with the abundant mammal fossils from the Untermassfeld site in Thuringia, Germany. The selection of the most representative European large mammal assemblages within the 1.2 - 0.9 Ma chronological interval was discussed in the frame of that meeting and subsequently published in detail [RF1]. Today, the Epivillafranchian is a widely accepted biochron and the localities dated to that time interval are primed for study and revision.
The two deposits from Atapuerca, level TE9c of Sima del Elefante and basal layers of Trinchera Dolina are rich in mammal fossils and their age covers the entire timespan represented by the Epivillafranchian. Our study focuses on the recorded carnivores, analysing taxa included in the original Untermassfeld proposal and adding new results from the Sierra de Atapuerca sites. Although the different Epivillafranchian sites have many species in common, also some differences in the faunal compositions are detected, which might be related with the respective special habitat conditions and/or taphonomic processes of the sites' formation. The study of the carnivores from the mentioned Sierra de Atapuerca localities complete our knowledge about the Epivillafranchian period as well as on the environment in which Europe's early humans lived.

Levantine overkill: 1.5 million years of hunting down the body size distribution

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Multiple large-bodied species went extinct during the Pleistocene. Many have pointed to changing climates and/or human hunting as the cause of these extinctions. We studied the causes of Pleistocene extinctions in the Southern Levant, and their subsequent effect on local hominin cultural complexes, by examining faunal remains in archaeological sites across the last 1.5 million years. We examined whether climate and climate changes, and/or human cultures, are associated with these declines. We recorded animal abundances published in the literature from 133 stratigraphic layers, across 58 Pleistocene and Early Holocene archaeological sites, in the Southern Levant. We used linear regressions and mixed models to assess the weighted mean mass of faunal assemblages through time and whether it was associated with temperature, paleorainfall, or paleoenvironment (C3 vs. C4 vegetation). We found that weighted mean body mass declined log-linearly through time. Mean hunted animal masses 10,500 years ago, were only 1.7% of those 1.5 million years ago. Neither body size at any period, nor size change from one layer to the next, were related to global temperature or to temperature changes. Throughout the Pleistocene, new human lineages hunted significantly smaller prey than the preceding ones. This suggests that continuously targeted the largest species in their environments, and when the largest species were depleted the next-largest were targeted. Technological advancements likely enabled subsequent human lineages to effectively hunt smaller prey replacing larger species that were hunted to extinction or until they became exceedingly rare.

Northeast Iberian Peninsula as a refuge ecosystem during the last Glacial Period: Insights from stable isotope and tooth wear analyses

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The Iberian Peninsula acted as a refuge region during the last Glacial Period as illustrated by the continuous human occupation recorded in the archaeological context of the Upper Paleolithic (ca. 45,000 to 12,000 years ago). In this southern part of Europe, terrestrial ecosystems maintained a vegetation productive enough to allow animals and their predators to persist over the harsh climatic conditions of the Last Glacial Maximum. Either the ecological traits of the large herbivores were flexible enough to adjust to contrasted conditions over time, or they could maintain the same type of diet and habitat due to the local attenuation of the climatic change.

In this communication, we will explore the diet and habitat/environment of horse (*Equus* sp.) and red deer (*Cervus elaphus*) from the Upper Palaeolithic occupation at the Serinyà sites of Arbreda cave (Aurignacian Gravettian, and Solutrean; ca. 42,000-21,500 years ago) and Bora Gran (Magdalenian; ca.16,000-14,700 years ago). Horse and red deer were important animal preys of the hunter-gatherers of the northeast Iberian Peninsula albeit in different proportions over time. We have conducted intra-individual sampling of enamel along molar teeth and measured the relative isotopic abundances of ^{13}C and ^{18}O in carbonate. The results should provide information on seasonal variation in diet and environment experienced by both species. In parallel, bones were selected to extract collagen and perform ^{13}C and ^{15}N analysis. Bone collagen remodels over the life of the specimens and provides a long-term information on diet and habitat. In addition, dental wear analyses were performed on the same specimens to investigate their long-term (mesowear) and short-term (microwear) dietary habits between grazing and browsing. Confronted to the results of the isotopic analyses, the dental wear analysis can contribute to disentangle the effects of the climate from those of the diet.

We will examine potential change in the niche of the horse and red deer before, around and after the Last Glacial Maximum and evaluate how the environmental conditions may have triggered changes in the diet and habitat of these two species. The results will also be considered from the point of view of human subsistence.

Stegodon SEAcross-ing: Swim, Shrink, and Disperse

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Elephants are known as ardent, skillful, and persevering oceanic swimmers. Smaller sea straits between the mainland and an island or between islands therefore do not represent major barriers for dispersals. *Stegodon*, phylogenetic relative of the family Elephantidae, followed a similar pattern. The fossil record of *Stegodon* in insular Southeast Asia and Wallacea illustrates a wide distribution area ranging from Java, through Flores and Sumba, to Timor, and stretching north to Sulawesi and the Philippines. Simultaneously, proboscideans underwent island dwarfing. En route to remote islands in Wallacea, dwarf stegodons in Flores for instance evolved c. 50 % body mass reduction relative to the ancestral species in mainland Southeast Asia. Reductions in body size have an impact on swimming performances and thus dispersal capabilities.

In order to examine the capabilities of *Stegodon* to disperse across insular Southeast Asia and Wallacea we applied SEAcross, an adapted version of the hominin sea crossing ABM. Because stegodons show island dwarfism, we developed a dwarfing scenario and determined crossing success rates (CSR) for a range of size categories.

We used oceanographic maps to determine critical features of sea straits: width, and current velocity and direction. The three parameters were applied to configure a standardized environment for each sea strait.

With respect to the *Stegodon* agents, we applied a physiological swimming model which allows to calculate optimum swimming speed and maximum distances by quadrupedal paddling from the relation between costs of transport and energy storage available. In this model, both variables, optimum swimming speed and energy storage, are dependent on size parameters, in particular head body length and body mass. Small-sized stegodons therefore have less energy at their disposal and swim with lower optimum speed. Consequently, they are less successful in crossing sea straits. Progressive dwarfing may render it impossible to cross a particular sea strait.

Our results identify and illustrate potential routes for *Stegodon* across the Sunda Shelf and Wallacea. We furthermore determine the maximum geographic distribution range in reach of stegodons of various size categories when moving across the focal islands.

New dietary insights for Homo spp. during the Pleistocene: evidence from the Italian peninsula over time

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The study of the paleodietary inference of our ancestors is crucial for understanding the relationship between evolutionary, cultural and palaeoenvironmental change. In this work we focus on the dietary habits that enabled *Homo* to face progressive climatic deterioration started with the Early-Middle Pleistocene Transition in the Mediterranean region and culminated in the Last Glacial Maximum. To do so, we rely on the traces left by food on tooth enamel (dental microwear analysis) of teeth from three *Homo* species (*H. heidelbergensis*, *H. neanderthalensis* and *H. sapiens*) that preserved antemortem wear from two key sites of the Middle and Late Pleistocene in central Italian Peninsula (Fontana Ranuccio, in Anagni and Fossellone Cave, in San Felice Circeo). Hence, dietary data on these samples are presented and discussed here for the first time. Besides important *Homo* remains, these sites have been selected for their abundant accompanying large-mammal fauna, associated lithic and bone industry, and excellent stratigraphic control data that altogether can provide in-depth climate and habitat information of the fossil human populations which occupied this region during the Pleistocene. Teeth from the Acheulean site of Fontana Ranuccio consist of several isolated remains, while fossils from Fossellone Cave (found together with Mousterian lithic industry in the case of Fossellone 3 and Aurignacian lithic industry in Fossellone 2) are comprised of several pieces included in mandibular or maxillary fragments. Our analyses reveal microwear differences (especially in frequency of microscopic scars and dimensions) among sites and species, especially between the *H. neanderthalensis* and *H. sapiens* samples from the same site (Fossellone, M. Circeo). Results suggest that different species probably based their diets on different trophic resources, at least occasionally, and had different subsistence strategies. These findings further indicate that significant dietary diversification occurred during the evolution of the *Homo* genus in the Italian Peninsula, to cope with climate instability and progressive deterioration.

Late Pleistocene Climates and Environments in the Tapi River Valley, India, and associated palaeoanthropological significance

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Many unique factors contribute to the potential of multidisciplinary research in South Asia to enhance the understanding of Late Pleistocene climates, *Homo sapiens* migrations, and megafauna extinctions. South Asia has diverse and dynamic climatic zones, favorable paleoenvironments, glacial biotic refugia, a long history of human occupation, high genetic diversity in present-day populations, and was an essential corridor for biotic interchanges between western Eurasia and eastern Asia. Discovery of later Quaternary human fossils would substantially improve our understanding of the evolutionary trajectories of our species in South Asia. The present study is a step towards this goal. A Late Pleistocene sedimentary sequence has been identified from the central Tapi River Valley, Maharashtra, India, where extensive Quaternary landforms, many Paleolithic sites, and extinct ostrich eggshell fragments have been recorded. A 14m sedimentary sequence has been sampled at 2cm intervals for multi-proxy analyses, including grain size distribution, the surface texture of quartz grains, palynology, ancient DNA, OSL dating, and stable isotope geochemistry. We report significant signatures of climate changes in this sediment sequence. The present study uses carbon and oxygen stable isotope geochemistry results on 196 carbonate nodules, the carbon isotope ratio of soil organic matter of 74 samples, and the total inorganic carbon percentage of 74 samples from the sediment sequence. Samples were analyzed for optically stimulated luminescence dating. Carbonate stable isotopes show distinctive combinations of proportions of C3 and C4 plants and generally low humidity during the Upper Pleistocene. Holocene carbon isotopes span most of the range of C3 to C4 plant cover, with generally higher humidity. The stable isotopic data and OSL dates are compared with available results from archaeological research in this region to infer the possible climate window(s) for prehistoric *H. sapiens* to expand into the Indian subcontinent.

The timing and ecological consequences of Pleistocene megafaunal decline in the eastern Andes of Colombia

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Examining the ecological consequences of the Late-Quaternary megafaunal extinctions within biodiversity hotspots is crucial for our understanding of the potential consequences of contemporary extinctions. We present the first multi-species record of spores of coprophilous fungi (SCF) from Monquentiva and the high Andean forests of Colombia to reconstruct Late-Pleistocene and Holocene megafaunal abundance. Fossilised pollen and charcoal are used to examine the consequences of megafaunal declines on the surrounding vegetation and fire activity. Our SCF record indicated the presence of Pleistocene megafauna at least since 30,290 BP, with two waves of megafaunal decline at ca. 22,900 and 10,990 BP. At Monquentiva, megafaunal decline in the early Holocene resulted in transitional non-analogue vegetation, a loss of some herbivore-dispersed plant taxa, an encroachment of palatable and woody flora, and a rise in fire activity. Differences with other published South American records suggest that ecological consequences of megafaunal declines were habitat-specific. Overall, we show that ecosystems in the eastern Colombian Cordillera were highly sensitive to the decline of megafaunal populations. Under the current biodiversity crisis, management and conservation efforts must account for the effect of local herbivore declines on the dispersal of certain plant species, on fire activity and the potential loss of ecosystem services.

Changes of the objective in the lithic tools production during the Uluzzian and the Aurignacian of Grotta Serra Cicora A (Nardò – Lecce, Southern Italy)

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Grotta Serra Cicora A (SCA) opens in the Mesozoic limestone of the Park of Portoselvaggio (Nardò, LE) and it's part of an important cave system frequented during Paleolithic in which the researches mainly concentrated during the 60s and the 70s of the last century. The stratigraphic sequence of this cave testifies the frequentations of *Homo neanderthalensis* and the ancient diffusion of *Homo sapiens* in Italy.
The "Museo della Preistoria di Nardò" has lately started the review of the collections as part of a wider project aimed at the reconstruction of the evolution of the coastal landscape in relation to the organisational strategies of the territory developed by the human groups.
One of the main purposes of the new researches is to implement the available data on the transitional phases from Middle Paleolithic to Upper Paleolithic and, in this framework, the update of the data coming from SCA is an important opportunity to understand the existing relationship between the Uluzzian of the Neretina coast and the rise of the following Aurignacian and the implication of this substitution on a territorial and extraterritorial scale.
In this work we display the preliminary results of the study of the Upper Paleolithic lithic tools found in the external survey realized by E. Borzatti and currently preserved in the Museum. In the stratigraphic sequence, the reconstruction of the technical system of production highlighted a relevant change in the technical behaviour. This change finds confirmation both in the morphotechnical and in the dimensional characteristics of some categories of tools. From the analysis it emerges that there is a specific selection of the raw materials and the introduction of exogenous lithotypes.
The changes that we can observe open the possibility to acquire more detailed information about the group mobility and the organisation of the activities. The prosecution of the studies goes in this direction, finalised on one side to reconstruct the environmental changes and the taphonomic processes, on the other to understand the cultural aspects such as the identification of the raw materials procurement areas, the techno-functional analysis of the tools and the faunal resources management.

European-scale agent-based model to track anthropogenic and natural impacts on vegetation during the Last Interglacial and the Early Holocene

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Anthropogenic impact on the environment started long before the spread of agriculture. Available ethnographic and Last Interglacial and Early Holocene archaeological evidence show that not only climatic fluctuations, megafauna activities and natural fires impacted landscapes, but also that foraging societies altered their occupation areas via vegetation burning. Because of the complexity of landscape dynamics, it is challenging to evaluate and distinguish different types of impact in proxy-based reconstructions. Here we present an agent-based model (ABM) designed to track different types of impact on vegetation with specific focus on the role of hunter-gatherer vegetation burning during the Last Interglacial and the Early Holocene.
The European-scale ABM was implemented in Netlogo 6.2.0. The following input datasets were used: GTOPO30 digital elevation model, WISE dataset for distribution of large rivers and lakes, output of a dynamic vegetation model (CARAIB), pollen-based estimates of past land cover obtained from the REVEALS model and estimations of megafauna plant consumption. The temporal resolution of the ABM model is one year, and the spatial resolution is 10 km. This model includes four types of impact: climate, human-induced vegetation burning, natural fires from lightning and megafauna vegetation consumption. Every simulation step is compared against REVEALS estimates to define parameter values which lead to matching pollen-based estimations. To quantify the intensity of each source of impact, their modifications are tracked during simulation runs. Additionally, sensitivity analysis identifies the key parameters which determine the intensity of anthropogenic impact.
The preliminary results show that it is possible to distinguish and quantify the different types of impact if the chosen datasets are combined in a continental ABM. Such an approach allows one to clarify the role of each source of impact in interglacial landscape dynamics. The future steps include production of maps to illustrate possible scenarios of modified vegetation.
The research is financed through the European Union's Horizon 2020 research and innovation programme within the TERRANOVA project, No 813904 and supported by the Liveable Planet program of Leiden University. This work was performed using the compute resources from the Academic Leiden Interdisciplinary Cluster Environment (ALICE) provided by Leiden University.

New evidence for human-lion interactions during the Middle Palaeolithic

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Large carnivores have played a pivotal role in the behavioral and cultural evolution of the hominin species. By competitive pressures, niche partitioning, and ever-shifting relationships between predator and prey, the human lineage has adapted to coexist with its competitors on the landscape. The lion is one of the most formidable predators humans could encounter. Today, just as during the Pleistocene, this large gregarious felid is a specialized hyper-carnivore that often dominates the trophic chain of the environment in which it lives. It is, therefore, not surprising that lions held distinctive meanings among Paleolithic human groups. The multilevel relationship between *Homo sapiens* and lions is well exemplified by the representations of the big cat in European Upper Paleolithic art and the increasing presence of lion remains in anthropogenic assemblages up to the end of the Pleistocene. However, the evidence for human-lion interactions before the arrival of our species in Europe is comparatively scarce and scattered.

Here, we report the discovery of new evidence for Neanderthal-cave lion (*Panthera spelaea*) interactions during the Middle Paleolithic. The recovery of distal phalanges at least 190 ka old from Einhornhöhle, Germany, represents the oldest evidence of large felids' pelt usage in the archaeological record. This new evidence hints at the socio-cultural importance of lions for central European Neanderthals. In addition, we present the results of the first systematic taphonomic analysis on a cut-marked lion skeleton dated to 48 ka found at Siegsdorf. Our results suggest that the predator was intentionally killed and the carcass processed at the kill site before being abandoned. This contributes to a unique snapshot of Neanderthal hunting behavior.

This new evidence suggests that lions were not passive antagonists for the Mousterian foragers but an active part of their landscape. We conclude that Neanderthals could engage big cats economically and culturally, as *Homo sapiens* did later – and continue to do today.

Session 112: Micromorphology as a tool in Quaternary studies to reconstruct changes in natural and anthropogenic sequences

Late Quaternary paleoenvironmental changes in the Homo-bearing karst landscape of Lamalunga (Altamura, Italy): pedogenesis and geomorphic processes from field scale to micromorphology

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A multidisciplinary approach was applied to assess the major paleoenvironmental changes occurred from the middle Pleistocene to the Holocene in a karst environment of South Italy, where an entire skeleton of Homo neanderthalenis of middle Paleolithic age (known as homo of Altamura) was discovered in a cave 30 years ago. The landscape consists of a small, gentle-flanked fluviokarstic valley, where there is the opening of the Homo-bearing cave, which has captured with a regressive upslope erosion a paleo-doline formed on Creteacous limestone. On top of the bedrock, a pedostratigraphic succession includes an older, truncated reddish paleosol with carbonate accumulations unconformably overlain by a grey tephra, locally reworked, sourced from the nearby Vulture volcano and dated ($^{40}Ar/^{36}Ar$) to 320±70 ka. The whole succession is buried by a brown soil developed on slope deposits with angular clasts, which exhibits cm-thick terrestrial carbonate beds consisting of composite micritic crusts dated (U/Th) to 22 and 17 ka. The upper carbonate level is overlain by a dark brown topsoil. Physicochemical, mineralogical and micromorphological analyses allowed us to reconstruct the interplay between pedogenic and geomorphic processes in the light of major paleoclimatic changes. XRPD analysis of all soil horizons displayed peaks of calcite, quartz, feldspar and mica, pointing to an allochthonous siliciclastic input in addition to the local carbonate parent material. Oriented specimens of the clay fraction revealed the occurrence of illite/smectite mixed layers and kaolinite as pedogenic clay minerals, which depict a moderate to high degree of soil development. Soil thin sections showed clay coatings with degeneration features and pedorelicts including similar illuvial pedofeatures in the lower paleosol. These findings suggest interglacial-like, temperate or warm humid climate conditions, followed by geomorphic instability. Lenticular microstructure with banded fabric developed in the tephra, indicates ice lensing due to freeze-thaw cycles, suggesting an overprinting of periglacial conditions. Some clay coatings and Fe-Mn segregations were detected in the intermediate soil. The carbonate pedofeatures, filling pores or variously impregnating the pedogenic matrix, displayed precipitation/dissolution features in response to cyclical changes from drier to moister conditions. Similar features were observed in both the carbonate crusts, likely controlled by stadial/interstadial shifts.

Site formation and context of human occupations at the Paleolithic site of La Ferrassie (Dordogne, France)

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The Paleolithic site of the "*Grand abri*" of La Ferrassie (Dordogne, France) is one of the best-known Middle and Upper Paleolithic sequences in Europe. Excavations at the site have spanned more than a century and uncovered rich archaeological assemblages associated with the Mousterian, Châtelperronian, Aurignacian and Gravettian technocomplexes. As part of renewed excavation, here we report on the geoarchaeological results from two excavation sectors to understand both the depositional history of the sediments and their implications to understand human occupations at the site. Originally a karstic cave, the stratigraphic sequence in the Western Sector comprises first fluvial deposition (Phase I), followed by soliflucted deposits and accretion cones emanating from an upper platform (Phase II) and, finally, spatially restricted channeling (Phase III). Most archaeological assemblages are associated with Phase II and reflect an interplay between occupations directly in this area and bones and artifacts sliding down the slope from the upper platform. Unlike in the Western Sector, in the Northern Sector - situated along the limestone wall and several meters inside the footprint of the cave - cold features dominate the entirety of the sequence; we interpret these as being linked to microenvironments specific to this location of the karst rather than to general (external) climatic conditions. Relevant is the identification of patterned ground formation in this area, which can be clearly linked to the "monticule" features first reported by Capitan and Peyrony and erroneously interpreted as anthropogenic in origin. Our geoarchaeological results point to a large and complex karst system, with distinct depositional sources and often locally independent sedimentary histories throughout its extent. These formation pathways have differently impacted the main occupation areas and resulted in distinct degrees of preservation of the archaeological assemblages throughout the different areas of the site.

The Châtelperronian in context: Micromorphology studies of the Middle to Upper Paleolithic transition at Quinçay (France)

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The French cave site of Quinçay – also known as Grand Roche de la Plématrie - represents one of the few multi-layered Châtelperronian sites in Europe. The site was initially excavated by Leveque (1968-1990) and has been the target of renewed multidisciplinary excavations since 2020. Ongoing geoarchaeological research at Quinçay has re-examined the stratigraphic framework and provided key insights into site formation processes. The site is a karstic cavity with a complex set of depositional environments and distinct degrees of organic preservation throughout the sequence. The basal deposits are affected by intense phosphatization associated with guano inputs that both predate and are synchronous with the Mousterian and first Châtelperronian occupations. Successive events of roof fall are hypothesized to have widened the cave's entrance and contributed to a marked change in the geochemical environment inside the site. Subsequent Châtelperronian occupations have good bone preservation and sedimentary inputs related to contributions from allochthonous sources. The uppermost levels are less rich archaeologically and capped by spatially patchy aeolian deposits. These are overlain by massive limestone boulders associated with a subsequent collapse of the cave roof. Interestingly, the entirety of the sequence is affected by cryoturbation with cold features clearly discernible in all studied thin sections. In all, our high-resolution micromorphological studies demonstrate a complex and dynamic system of biogenic, geogenic and anthropogenic processes and provide new insights into the nature of the Middle to Upper Paleolithic transition at the site.

Reconstructing site formation processes and archaeological preservation at the open-air Aurignacian site of Breitenbach, Germany

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Upper Palaeolithic open-air sites are poorly known. This is partly due to a long-lasting research bias towards cave and rockshelter sites, more easily recognisable in the archaeological record. By contrast, the interpretation of intra-site data from open-air Late Pleistocene sites is limited by a number of challenges that might include the excavation techniques, the occurrence of post-depositional disturbances, the applicability of the interpretative models developed (especially those deriving from a particular ethnographic context), and the unequal balance between the quantitative analysis of the record and its interpretation. Addressing these issues entails the high-resolution characterisation of lithological boundaries and site formation processes to document changes in the depositional contexts. This goal is better achieved with a microstratigraphic approach, which allows the study of deposits to a great detail, further contributing to the identification of the physical and chemical postdepositional processes that may have affected the site since its abandonment.

This contribution focuses on the micro-contextual study of the occupation horizon and immediately adjoining layers at the open-air Aurignacian site of Breitenbach, Sachsen-Anhalt, Germany, through the integration of micromorphological and FTIR analyses. Results shed light onto the depositional and post-depositional histories of the site, contributing to elucidate the integrity of the find-bearing sediments and the geoarchaeological impact of the processes of disturbance. Particular attention has been paid to exploring individual components of spatial behaviour and pyrotechnology to explore the habitation patterns of Aurignacian hunter-gatherers.

Interpreting multi-scale data from Late Pleistocene hunter-gatherer landscapes: examples from open-air sites in northern Malawi

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The Karonga area in northern Malawi has a rich record of Middle Stone Age (MSA) hunter-gatherer activity, evidenced by lithic artefacts found in remnants of an alluvial fan system. Excavations revealed several intact assemblages including among others at Chaminade II, with occupations dating between 47-30 ka, the site complex of Bruce, with multiple occupations between 51-31 ka, and Mwanganda´s Village, which had a terminal MSA occurrence dated between 26-15 ka. Geoarchaeological and environmental efforts have focused on reconstructing the types of physical environments that attracted MSA foragers. Challenges were posed by poor organic preservation, limited possibilities for dating, and high complexity of site formation histories. Post-depositional processes included bioturbation by termites, mineral weathering, groundwater fluctuations, as well as the formation of iron-manganese nodules, calcrete paleosols, and laterites. The overall redness and homogenized macroscopic appearance of the sediments may raise the impression that each site followed a similar formation pattern. However, through careful field analysis and micromorphology, we reconstructed unique site formation histories for each site. Through coupled thin section and stable carbon and oxygen analysis of pedogenic carbonates we were able to obtain on-site environmental data, supplemented by radiocarbon dates, providing an additional control for the chronology of the sites besides the extensive dating of sediments with Optically Stimulated Luminescence.
Combining data from on-site microarchaeological analyses with semi-local and regional proxies (e.g., palynology and phytoliths), we discovered that late MSA activity and tool production occurred in locally more open riparian environments within evergreen gallery forest, surrounded by a regional vegetation dominated by miombo woodlands and savannah. Additionally, MSA hunter-gatherers exploited the confluence of river and wetland areas along the shores of Lake Malawi, which likely served as important corridors for the dispersal of biota. The results of our work show that by integrating ecological and chronometric data within a framework of site formation histories, it is possible to obtain more dimensional interpretations of late Pleistocene forager environments than typically expected in tropical environments with poor organic preservation.

Stepping Back in Time: A multi-proxy study of micromorphological samples from human footprints and associated wetlands at the Pleistocene-Holocene transition in the Great Salt Lake Desert, Utah

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Reconstruction of paleoenvironments at the Pleistocene-Holocene transition in North America has attracted significant research attention, and the basin of pluvial Lake Bonneville has served as a critical laboratory in the Desert West. Changes in terrestrial and stratigraphic records deposited during the late Pleistocene regressive phase of Lake Bonneville provide information on regional climatic drivers. Locally, these changes influenced the wetland habitats that were key to early occupation of the Great Basin by humans, ca. 13,000–9500 cal yr BP. Several sites with significant preservation of early human activity in Lake Bonneville have been recorded within U.S. Air Force-managed lands of the Great Salt Lake Desert in western Utah, USA, including the Wishbone Site, a hearth-side Haskett campsite preserving the earliest documented evidence for human use of tobacco. Previous paleoenvironmental studies in this area demonstrate that between ~13,000–12,400 cal yr BP, a shallow lake formed fed by overflow from neighboring Lake Gunnison. Multiple lines of paleoenvironmental evidence show a transition to warmer conditions by the early Holocene, leading to desiccation by, or intermittently within, the middle Holocene. As the lake dried up over time, a lush freshwater marshland associated with river flow and groundwater discharge formed a shallow deltaic system across the basin landscape.

The recent discovery of 88 human footprints in the sediments associated with this shallow deltaic system and in proximity to the Wishbone site has motivated a closer look at the micro-scale development of the wetlands and associated vegetation communities, with two primary goals: 1) to better constrain the dates of the geomorphological units and eventually the footprints themselves, and 2) to better understand precise changes in vegetation communities in relation to human presence in the basin and early human exploitation of those resources. To that end, this paper presents a multi-proxy study of micromorphological samples taken from the geological sections exposed near the archaeological sites and from the footprints themselves. Phytoliths, lipid biomarkers, compound specific δ^{13}C and δ^{2}H isotope analysis of long chain alkanes, and micromorphological sediment data are analyzed to address these research goals.

Geoarchaeological evidence of Late Holocene land use transitions in Northern Mesopotamia from the infilling od Assyrian canals

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In Northern Mesopotamia (present-day northern Iraq), during the Neo-Assyrian Empire, a complex system of canals was built to increase the surface of cultivable land and improve the efficiency of the irrigated waterscape of the hinterland of Nineveh and other major urban centres. The main aims of these facilities for water harvesting were to grant socio-economic prosperity to the entire Neo-Assyrian Empire. In the late 7th century, political instability led to the Assyrian state's rapid downfall, triggering the defunctionalisation of the canal systems and the formation of a sedimentary infilling. We investigated the natural and anthropogenic processes in charge of the formation of the infilling at three different portions of King Sennacherib's Khinis canal system. Along the stratigraphic sequences, we identified water-lain sediments, desiccation features, gravel-bearing colluvial deposits, and pastoral occupation layers, anchoring the deposit to radiometric dating and contextualising it against the known regional climatic history. Phases of use, abandonment and repurposing of the canals derived from pedostratigraphic analysis evidenced a significant shift in land use from agriculture to pastoralism after the collapse of the Neo-Assyrian Empire, thus suggesting a dynamic adaptation and resilience of the local communities in response to the joint effects of climatic transition towards aridity in the Meghalayan and geopolitical instability.

Dismantling urban Dark Earths. The combination of micromorphology and phytoliths analyses to understand past activities in the early medieval layers of DIVA (Antwerp, Belgium)

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Dark Earths are a ubiquitous phenomenon in urban contexts. They are typically thick, dark coloured, humic, and homogeneous layers embedding high amounts of information concerning past human activities. Their study and interpretation are not easy, since there are no clear boundaries in their stratification (Nicosia et al., 2017). Recent excavations on the site of DIVA (Antwerp, Belgium) have uncovered between 1 and 2 meters thick Dark Earth, chronologically bracketed between the end of the Gallo-Roman empire and the 11th century, corresponding to the period when the city begins to emerge. The site was located just next to the 10th century fortified nucleus or 'burcht' of Antwerp. As written information for this period is not abundant, and given the difficulty of understanding Dark Earth based on field data alone, multi proxy approaches are key to come to a better understanding of early city formation.

In our contribution we will present the results of the micromorphological study and the phytolith analysis on thin sections. This integrated study has been realized to better understand the economic activities carried out during the mentioned period, and consequently the formation processes that generated the Dark Earths. Micromorphological results allowed us to distinguish different strata derived from different activities sequenced as follows: 1) agricultural activities in a dry environment, 2) activities close to a settlement, 3) and walked surfaces within a settlement and stabling with more water saturated conditions. The phytolith record described in agricultural layers is dominated by grasses from the C_3 *Pooideae* subfamily, commonly found in humid and temperate environments. Distribution patterns are dominated by isolated and clustered phytoliths, suggesting postdepositional processes (anthropogenic, biogenic or a combination of both) that transported them from their original position. This study sheds new light on the origins of Antwerp and is in agreement with previous results obtained in other sites of the city, where ground rising and agricultural activities were also documented.

Session 115: Palaeoenvironmental research in SW Asia: Recent advances & future opportunities

Important findings from the TephroMed project I: Synchronising two important ICDP records of the eastern Mediterranean region using tephra

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The eastern Mediterranean region is crucially located between two contrasting climatic zones and precipitation regimes, the humid Mediterranean climate to the north and the hyper-arid Saharo-Arabian desert belt to the south. Lake sedimentary archives provide important insight into past hydroclimatic variability through multiple environmental proxies. However, chronological uncertainty prevents detailed insight into regional climatic (a)synchronies. The application of tephra (volcanic ash), both visible and non-visible (cryptotephra), can be a powerful chronologic tool in correlating palaeoclimatic records, particularly over vast distances.
The TephroMed project aimed to precisely synchronise two important ICDP palaeoclimatic records from eastern Mediterranean through the use of tephrostratigraphic investigations: Lake Van, Turkey (PALEOVAN) and The Dead Sea, Israel (DSDDP). Both records have undergone palaeoenvironmental and climatic reconstructions which have indicated contrasting past regional responses to large-scale climatic events. Though both records are dated through absolute and relative methods (radiocarbon, U-Th, varve counting, wiggle-matching), inherited large chronological uncertainties do not allow detailed insight into the potential climatic time-transgressive nature between the two sites. Yet, both records have tephra deposits within their lacustrine sediments, highlighting the potential to facilitate the alignment of both records using tephra.
Here, we present new volcanic glass chemical data from key tephra layers in both Lake Van and The Dead Sea ICDP cores. The use of major, minor and trace element volcanic glass chemistry (EPMA and LA-ICP-MS) allows correlation of tephra layers between the two cores, providing an important chronological alignment. Additional correlations to other important climatic archives in the Mediterranean have been made with the Dead Sea and Lake Van, improving the chronology for these records. As a result of finding these isochronous markers, we can now start to answer questions associated with regional expression of past climatic events and their temporal transgression.

Exploring the challenges of linking local and inter-regional archaeological and environmental records of Southwest Asia: the example of Ararat-1 cave (Armenia)

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One of the major challenges in archaeological research is to create a cause-and-effect relationship between environmental oscillations and changes in material culture. Yet, still, the construction of detailed arguments about causality in such interactions remains a persistent pursuit. Establishing a finer chronological resolution that enables us to move beyond correlation to causation, remains as much a theoretical task as a methodological one. Climatic fluctuations during Marine Oxygen Isotope Stage 3 (MIS 3, c. 60 – 27 ka) have been suggested to be one of the possible triggers of the Middle to Upper Palaeolithic (MP to UP) transition in Eurasia.

In this lecture, we will present the recent results of the excavations in Ararat 1, a cave located in the Ararat Depression, Armenia. Based on a combination of sedimentological and geochronological (luminescence, radiocarbon, and tephrostratigraphy) techniques, together with analysis of the faunal remains and lithic assemblage, the site can be dated within the 50-35 ka interval. Our preliminary understanding of the available proxies at the site suggests a stable ecological niche of a semi-desert with no major changes occurring throughout this time interval. The multiscale chrono-environmental framework at Ararat 1 provides evidence for the long-term co-existence of Middle and Upper industries in the Armenian Highlands and the neighbouring regions. Similar to the varied local ecological manifestations of climatic oscillations during MIS 3 in Southwestern Asia, such major "events" like the Middle to Upper Paleolithic are asynchronous societal processes displayed differently geographically, and of myriad societal mechanisms. The ongoing excavations and research at the site would aim to refine and clarify the possible connections between nuanced ecological fluctuations with the intensity of occupation at the cave.

Changes in minerals during accumulation of the loess-paleosol sequence at Baluchabad, Northern Iran

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Phyllosilicates (clay minerals) are formed through the weathering of silicate minerals over time which is strongly dependent on environmental conditions, i.e. climate, and can thus provide information on paleoenvironmental conditions during their formation. Clay minerals in loess deposits are mainly inherited from the source sediment, however, post-depositional weathering can also alter clay minerals by neoformation, transformation, and illuviation. The Baluchabad loess-paleosol sequence is characterized by twelve paleosols grouped in four pedocomplexes. The sequence is 54 m thick and accumulated on the northern foothills of the Alborz Mountains near Kalale city. For mineralogical analysis, 22 samples of the clay fraction in paleosols and underlying loess horizon were selected and saturated with K, and Mg. The K-saturated samples were heated at 550 C furthermore Mg-saturated samples were treated with Ethylene Glycol solvation. Treated samples were examined by an X-ray diffractogram machine. X-ray diffraction pattern of oriented samples showed the main clay minerals include smectite, chlorite, illite, and kaolinite. Previous studies showed that their presence in north Iranian loess-paleosol sequences had been inherited from the sediment source, nonetheless, pedogenetic processes under different environmental conditions in paleosols can change their abundance. Comparing the amount of smectite in paleosols with the loess below them shows that the amount of smectite in paleosols has increased, which indicates warmer and more humid environmental conditions with poor drainage. Also, by comparing the paleosols with each other, the amount of smectite increases by moving from the top to the bottom of the section revealing increases in pedogenic processes intensities at the bottom of the Baluchabad profile is more than the paleosols near the surface. In addition, the concluded result of mineralogy corroborates and is in accord with the micromorphology and magnetic susceptibility results. Therefore, the mineral abundance changes in paleosols demonstrate weathering and transformation of clay minerals during their formation, which indicates changes in pedogenesis processes.

5,000 years of environmental change and anthropogenic impact deduced from gravity sediment cores from Lake Sevan, Armenia

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Lake Sevan is located in eastern Armenia close to the border to Azerbaijan. With a length of ~70 km, a width of ~50 km at an altitude of 1900 m a.s.l. it is one of the largest freshwater high-mountain lakes. The lake itself is structured in two parts: the larger southern part called Big Sevan has a maximum water depth of 34 m whereas the northern smaller part called Small Sevan has a water depth of 65 m in the centre and a maximum water depth of 83 m close to the northern shore as a result of active tectonics.

Up to now, only limited information exists about more distal profundal sediments from Lake Sevan. Studies, which have been carried out so far, focused on micropaleontological investigations such as ostracods or pollen. Chemical investigations let alone multi-proxy approaches have rarely been done. In order to explore the further potential of sediments from Lake Sevan we recovered 16 gravity cores (51-141 cm length) from both parts of the lake in October 2021. All cores are clearly characterised by a more homogenous sedimentation in the lower part of the core and a more diverse succession in the upper part, which can likely be attributed to intense water level regulations since Soviet times, and anthropogenic impact in the subrecent past. In addition to that, the longest recovered sediment sequence (SEV21-6; 141 cm length) is finely laminated in the bottom part.

Radiocarbon ages on two cores from the centres of each lake part indicate a rather constant sedimentation rate since 5,000 cal BP in Big (SEV21-6) and 3,000 cal BP in Small Sevan. These chronologies are currently checked using paleomagnetic secular variation stratigraphy. Subsequently, they will be used in combination with a multi-proxy approach consisting of grain sizes, CNS, XRF-scanning and visible-spectrum scanning reflectance spectroscopy (VIS-RS) analyses as well as micropaleontological parameters (pollen, diatoms) for paleoenvironmental reconstructions.

Middle to late Pleistocene human-environment dynamics at the arid margin of the Levant: integrating archaeological and paleoclimatic records from the Greater Azraq Oasis Area, Jordan.

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The Azraq Basin is an approximately 12,000 km^2 endorheic drainage system in the Syro-Arabian Desert at the eastern margin of the Levant. The centre of the basin, which we refer to as the Greater Azraq Oasis Area (GAOA), is characterized by a saline mudflat with until recent times two wetlands on its northern end. Desiccation of these wetlands in the early 1990s and subsequent construction activities have exposed middle and late Pleistocene wetland deposits containing abundant Lower, Middle, and Upper Palaeolithic stone tools and faunal remains. Landscape-focused geoarchaeological research has since demonstrated that the past c. 350 ka in the GAOA are characterized by paleoenvironmental fluctuations that shifted the quantity and distribution of freshwater resources, ranging from expansive waterbodies and wetland landscapes to desert refugia characterized by isolated spring pools and wet meadows. Such dramatic shifts in the ecosystem would have influenced seasonal faunal and floral resource availability and thus hominin mobility decisions and settlement patterns during the Paleolithic. Results also indicate that the steep climatic gradient from northwest to southeast across the southern Levant likely extends back into the Middle Pleistocene. In this paper, we present results of our ongoing efforts to integrate the middle to late Pleistocene archaeological, paleoenvironmental, and paleoclimatic records of the GAOA, including new data concerning lithic technology and faunal remains, as well as from microbotanical, isotopic, geochronological, and protein residue analyses. As the available data sequences are fragmentary, something commonplace in arid contexts, elucidating long-term human-environmental dynamics requires a multi-scalar approach that draws on a variety of paleoenvironmental archives that must be combined with a well-developed understanding of landscape evolution. Despite this challenge, developing a more detailed understanding of the environmental and archaeological history of this period is essential to evaluating the eastern arid margin of the Levant played as a corridor for dispersals of Pleistocene hominins throughout Southwest Asia.

The Paleoclimate Implications of the Vedi Travertine (Ararat Valley, Armenia)

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The analysis of paleoenvironmental records coupled with records of human behavior provides valuable insight to archaeologists wishing to understand how and why hominin behavior changed throughout the Pleistocene. Though the archaeological record of the Armenian Highlands and the Southern Caucasus is rich, the region lacks long term continuous records of paleoclimate change to compliment these records of human behavior. To address this gap in paleoclimate research in the region, here we present initial results of a coring project together with geomorphological mapping on the Vedi travertine, a large (~30 m) sequence of Quaternary spring deposits in the Ararat Valley, Armenia. Uranium series dating will provide chronological constraints on this core, and stable isotope ($\delta^{18}O$ and $\delta^{13}C$) and trace metal analysis will be used for paleoenvironmental information. Along with these traditional analyses, novel analyses of matrix-bound biomarkers, such as *n*-alkanes, will provide complimentary paleoenvironmental data. Together, the data from this travertine core will provide an important record of hydrological change in the region.

Tracing cryptotephra to Levantine archaeological and environmental records: successes, challenges, and future steps.

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Studies of marine, lake and archaeological sites in the wider Mediterranean region have demonstrated the value and utility of non-visible volcanic ash layers (cryptotephra) in the correlation and dating of climate and archaeological records. In recent years, significant advances in this avenue of research have been made, most notably with the results of the RESET project. However, to date, only minimal investigations have been made to expand the framework eastwards into the Levant, despite the rich and globally significant archaeological records present.

Here we describe the results of a renewed investigation, funded by the Leverhulme Trust, which aims to expand the application of cryptotephra to a number of Levantine Palaeolithic records. These records are crucial for understanding the timing of early Modern Human dispersals ‘out of Africa’, their interaction with Neanderthal populations during the Pleistocene and the role that climate may have played in these encounters. Seventeen sites were examined as part of the project with results focused here on those which have given the most notable ‘successes’ and ‘challenges’.

Cryptotephra concentrations in the Levantine sites, are in the majority of cases, exceptionally low and are frequently complicated by a mixed chemical signature. The potential volcanic source regions for these are numerous, with Italian, Aegean and Anatolian Volcanic Provinces all suspected as contributing to the deposits identified. To tease the maximum amount of information from these complex tephra records has required a forensic-style approach as well as advances in analytical techniques. These efforts have in part proven successful with at least one robust tephra being identified as originating from the Kos volcano and serving as a regional marker horizon during MIS5e.

Session 118: Cave deposits for in deep understanding Quaternary climate and environment

Innovative and interdisciplinary karst cave excavation of rare pre-LGM sediments in northern Norway

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Caves are extraordinary time capsules of past ecosystems and environments and their sediment deposits have great potential to answer questions regarding palaeoclimate, sea level change and landscape development. In high latitudes these deposits are crucial for better understanding the extent of the ice sheet cover and periods of retreat during the Quaternary glaciations. There are over 1100 known karst caves in Norway and around half of these have been mapped and investigated. Yet, deposits predating the last glacial maximum (LGM) are incredibly rare due to erosion and removal of sediments by flushing meltwater from the glaciers.
We capitalise on the excellent preservation conditions in a high-latitude (68°50'N) karst cave in northern Norway with an extra-ordinary rich pre-LGM faunal record, estimated to range in age between 70 000 and 120 000 BP. Sediments in the Storsteinhola cave system were excavated using optimised and innovative methods for comparative, interdisciplinary analyses from the fields of archaeology, geology, sedimentology, palaeozoology and ancient DNA. Chronology is established combining radiocarbon analyses of bone, cosmogenic nuclide burial dating of quartz-rich clasts, ^{230}Th/^{234}U dating of calcite speleothem and calcareous concretions, and optical stimulated luminescence and paleomagnetic dating of sediments. The upper part of the deposit consists of shallow marine sand and beach gravel from the Late Glacial, reflecting a high relative sea-level following the last deglaciation. Below are glaciolacustrine fines and glaciofluvial sandy gravel from period(s) with ice-cover, followed by a boulder-rich, crudely stratified diamicton. Within these layers we have identified a diverse number of Arctic related faunal taxa through a novel combination of bulk-bone metabarcoding and morphological identification. We combine sediment analyses with the detected faunal diversity for the reconstruction of the local palaeoenvironment and Scandinavian ice sheet history. Through our interdisciplinary research we obtain new knowledge for the glacial period in northern latitudes and highlight the importance of cave sites to research.

Stable isotopic signatures of fossilised rodent teeth from Naracoorte Caves: Insights into late Quaternary climate change in South-eastern Australia.

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Understanding impacts of past climate and environmental change on mammal communities is important for understanding dynamics of future ecosystem change. Stable isotope analysis of bioapatite from fossilised mammal teeth is a well-established technique for reconstructing past climate and vegetation; however, is underutilised at Australian vertebrate fossil sites. The Naracoorte Caves World Heritage Area (NCWHA) in South Australia, preserves abundant, owl-pellet derived late Quaternary small mammal fossil assemblages, providing ideal sample sizes to reconstruct temporally resolved climate and vegetation records using stable isotopes. In this study, we use isotope ratio mass spectrometry to analyse stable carbon and oxygen isotopic composition of bioapatite in fossil teeth from three Australian rodent species as a proxy for reconstructing palaeoclimate and palaeovegetation of the Naracoorte region. Lower incisor teeth from three species of the genus *Pseudomys (P. auritus, P. australis and P. shortridgei)* were sampled across 43 sedimentary layers from a palaeontological excavation in Blanche Cave (NCWHA) spanning from around 65 to 14 thousand years ago. This time period is significant as it covers human arrival on the Australian continent and the mass extinction of around 68 species of birds, reptiles, and mammals with body masses greater than 40 kg. The Blanche Cave deposit therefore captures environment prior to, during and following these important palaeoecological changes across the region. Our reconstructions of palaeoclimate and palaeovegetation from carbonate- and phosphate-bound components of bioapatite reveals change in the dominant vegetation type from open woodland to grassland at the time of the Last Glacial Maximum (LGM). Changes in the water regime also reveal a shift from cool and wet to warm and dry conditions in and out of the LGM. The results of this study demonstrate the potential for using rodents, which are commonly abundant in Naracoorte fossil deposits, to establish directly associated climatic and vegetation records, and provide an improved contextual framework for evaluating extinction events, such as Late Pleistocene megafauna extinction, in Australia. Our approach has the potential to be extended to megafauna, enabling better understanding of how large mammal communities responded to changes in climate and vegetation during the last glacial cycle and beyond.

Producing high-resolution 20th Century speleothem records: Milling, Laser-Ablation, and mixed methods dating on stalagmites from Madagascar and Australia

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High resolution analysis of recently growing speleothems and comparison with independent climate records can help determine which components of the hydroclimate system are recorded in speleothem $d^{18}O$ and trace element ratios. This includes local and regional rainfall amount, seasonality, evaporation, in-cave kinetic effects and more. However, at such young ages, low ^{230}Th accumulation reduces the precision of U-Th ages that make speleothems such powerful paleoclimate records at other timescales.
In this study we adopt a mixed methods approach to dating 20th and 21st century stalagmites that allows for absolute chronologies with sub-decadal accuracy. Our approach combines annual geochemical cycles, radiocarbon bomb-pulse modelling, collection dates, and conventional U-Th ages. We test our method on recently growing stalagmites from Careys Cave in Australia and Anjohibe in Madagascar, both of which contain short 20th century hiatuses. Using the new mixed methods age models, we compared high-resolution micro-milled $d^{18}O$ records with local rainfall station, satellite and reanalysis estimates of past rainfall. In Madagascar we show a tight coupling of stalagmite $d^{18}O$ and satellite rainfall estimates with less than 2 years age offset. This potentially opens the door to a paleotempestology record identifying tropical cyclone activity. With this we can examine whether past tropical cyclones have an outsized $d^{18}O$ impact relative to the already extreme rainfall amount. In Australia we show good coherence of stalagmite $d^{18}O$ and trace element ratios with historical droughts recorded at local meteorological stations. Seasonal correlations allow us to begin estimating potential biases in the stalagmite proxies. Overall, coupling stalagmite $d^{18}O$ records with recent independent rainfall indicators, which we term paleo-monitoring, allows us to build more robust and nuanced proxy interpretations, giving confidence in paleoclimate reconstructions of the more distant past.

Stalagmite-based paleofire reconstruction using organic biomarkers: a case study from cave KNI-51, tropical Western Australia

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Contemporary human activity is altering rates and intensities of wildfire, but the nature of fire activity prior to the modern era is poorly understood. Here we investigate the utility of a novel paleofire proxy: trace pyrogenic organic compounds in stalagmites. Polycyclic aromatic hydrocarbons (PAHs) are linked to burning of biomass and are transported downward through soil and bedrock by infiltrating rainwater and incorporated into stalagmites in underlying caves. We couple PAHs with *n*-alkanes, which may be used to infer past vegetation conditions, to provide complementary evidence of fire. In this pilot study, we have so far analyzed three fast-growing and precisely-dated aragonite stalagmites from KNI-51, a shallow cave in the fire-prone tropical savanna of Western Australia. The thin layer of fractured bedrock above the stalagmite chamber, coupled with a minimal soil layer allows quick transfer of combustion products to the cave system.

To test the stalagmite-paleofire link, we performed several experiments. First, we assessed the possibility of surface contamination on the stalagmites by measuring PAH and *n*-alkane abundances and distributions in sequential digestions. Second, because KNI-51 often floods and flood sediment is incorporated into the stalagmites, target compounds were measured in soils above the cave, sediments lining the stalagmite chamber floor, and flood-derived sediment incorporated within stalagmites as possible sources of these organic compounds. Third, we considered as additional sources other possible biological and geological influences, such as regional oil and gas fields or microbial activity. And fourth, satellite-mapped fires occurring proximal to the cave were correlated to PAH abundances in a recently active portion of one stalagmite.

The results support the contention that PAHs and *n*-alkanes in KNI-51 stalagmite carbonate likely reflect paleofire activity. While flood sediment contains PAHs, no significant correlation was found between target compounds and the presence of flood layers. We argue that biomass burning and the consequent fire-induced breakdown and particle deposition are the main sources of target organic compounds in these stalagmites. Given that karst is present in many fire-prone environments, and that stalagmites can be precisely dated and grow continuously for millennia, the potential utility of a stalagmite-based paleofire proxy is high.

High precision 230Th/U dating of tropical speleothems reveals decadal- to centennial-scale variability in soil carbon cycling and hydroclimate over the past 40 ka

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In recent decades, tremendous progress has been achieved in ^{230}Th/U dating of speleothems and other secondary carbonates, which allows for a wealth of continental hydroclimate reconstructions on absolute time scales. Here we demonstrate the feasibility of absolute decadal to sub-centennial age precision for speleothems from Larga Cave in Puerto Rico, which have U contents of 400–800 ng/g, and reveal a high, but well reconstructed initial ^{230}Th content. Age uncertainties achieve a median of <4‰, providing an excellent time control over the past 40 ka at multi-decadal to sub-centennial scale resolution.

Trace element records (including e.g., Mg/Ca, Cu/Ca, or Zn/Ca) and stable oxygen and carbon isotopes (δ^{18}O and δ^{13}C) indicate significant changes in hydroclimate, which are, however, decoupled to soil carbon cycling indicated through a high-resolution dataset of ^{14}C, i.e., the dead carbon fraction (DCF). While stable isotope and trace element time series track changes of the amount of rainfall, associated with prominent northern hemispheric millennial scale climate events such as the Dansgaard-Oeschger (D/O) events or Heinrich Stadials, the DCF pattern exhibits extreme centennial-scale variations with a large range from 20% up to more than 50%, reflecting three main soil carbon cycling states across the termination. During the Last Glacial Maximum (18–25 ka), DCF variability vanishes indicating minor soil carbon changes above the cave. In contrast, preliminary DCF results from the Holocene suggest a possible second stable soil carbon cycling mode and better ventilated soil.

Thanks to the combined study of high precision ^{230}Th/U and ^{14}C dating, the Larga Cave speleothem record will allow to detect abrupt changes in soil carbon cycling and host rock dissolution over large parts of the past 40 ka. Together with analyses of hydroclimate-sensitive proxies the relation to local and regional (hydro)climate on multi-decadal to millennial timescales can be investigated.

Temperature thresholds on Central America hydroclimate during the last glacial cycle

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Speleothem oxygen-isotope ($\delta^{18}O$) records from tropical and sub-tropical regions have been widely applied as proxy of regionally-integrated rainfall and monsoon strength variations, providing key insights on the processes controlling low-latitude paleoclimate dynamics . For instance, speleothem $\delta^{18}O$ paleo-monsoon records from East and Southeast Asia, as well as North and South America indicate a strong link between changes in orbital insolation and regional hydroclimate, suggesting that moisture availability and rainfall regimes are highly sensitive to insolation associated with Earth's precession cycles. However, some tropical monsoon regions, such as Central America document hydroclimate records that differ from the canonical orbital paradigm, implying that complex dynamics linked to ocean-atmosphere interactions and sea surface temperatures exert a more dominant control. Here, we present a replicated new, 130 kyr-long U/Th-dated speleothem $\delta^{18}O$ record from Guatemala, and discuss the relationship between orbital forcing, ocean-atmosphere thermodynamics, and hydroclimate response of the Central American Monsoon (CAM) during the last glacial cycle. Our data differ substantially from the gradual orbital summer insolation curve at 15°N and instead show abrupt wet-to-dry transitions partially coincident with autumn insolation minima, including monsoon weakening during MIS 5b and 5d, coeval to periods of autumn insolation minima, lower greenhouse gases concentrations, and tropical Atlantic surface temperatures (SSTs) below 27.5 °C. These dry intervals coincide with some of the Northern Hemisphere cold events known as Heinrich and Greenland Stadials. Contrarily, negative $\delta^{18}O$ excursions (stronger monsoon regimes) are documented during interglacial insolation maxima, and are synchronous to intervals where greenhouse gases were higher and tropical SSTs above 27.5 °C. In addition, no clear Dansgaard-Oeschger cycles are identified in our new record during the MIS 3 and 2, suggesting that regional hydroclimate in our study area is not strictly linked to the millennial-scale variations of the Intertropical Convergence Zone position, despite our close vicinity to the tropical North Atlantic. We conclude that CAM convective systems respond to temperature thresholds modulated by atmospheric heating and ocean-atmosphere-land interactions that can cause abrupt monsoon collapses independently of the background climate state.

Subglacial speleothems: a promising emerging archive in paleoclimate science

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Speleothems from cold high-latitude or high-elevation caves are very sensitive paleoenvironmental archives because they form close to the freezing point of water, and Arctic or Alpine soils – the source of carbon dioxide for karstification – are thin and vulnerable. Therefore, it is widely assumed that cooling of the climate will cause an interruption in the growth of these speleothems. However, this ignores the fact that atmospheric cooling leads to a lowering of the equilibrium-line altitude and expansion of glaciers. A temperate glacier overflowing a karst system prevents the latter from freezing. Although glacials were generally less humid than interglacials, caves in mountain regions, for example, had a much higher chance of being covered by glaciers (and thus kept "warm") during cold climatic periods than caves at lower elevations, which were often in the permafrost zone. These periods without frost in caves that were covered by temperate glacier ice can be recorded by speleothems if the host rock contains disseminated pyrite, a microscopic sulfide mineral that is widely distributed in impure limestones, dolostones and marbles. Recent and ongoing research in caves of the Eastern and Western Alps in Europe has shown that speleothems from such subglacial environments are widespread and provide unprecedented opportunities to obtain records of environmental change covering the long glacial periods. When combined with the study of conventional warm-climate speleothems controlled by soil dynamics and locally present cryogenic cave carbonates (as robust indicators of the presence of paleo-cave ice accumulations), the possibility opens up to exploit the full paleoclimate potential of Arctic and Alpine caves on glacial-interglacial time scales.

Session 120: Volcanic impacts on climate and society

High resolution sulfur isotopes from ice cores: improved estimates of the volcanic forcing of climate

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The record of the volcanic forcing of climate over the past 2500 years is reconstructed primarily from sulfate concentrations in ice cores. Of particular interest are stratospheric eruptions, as these afford sulfate aerosols the longest residence time and largest dispersion in the atmosphere, and thus the greatest impact on radiative forcing. Sulfur isotopes can be used to distinguish between stratospheric and tropospheric volcanic sulfate in ice cores since stratospheric sulfur aerosols are exposed to UV radiation which imparts a mass independent fractionation. Thus, sulfur isotopes in ice cores provide a means to identify stratospheric eruptions and calculate the proportion of sulfate deposited from a volcanic event that came the stratosphere, allowing us to refine the historic record of explosive volcanism and its forcing of climate. Here we present high-resolution (sub-annual) sulfur isotope data from both Greenland and Antarctica across a suite of unidentified eruptions from the anomalously cold decades of the 530s, 1450s and 1600s, as well as the newly identified eruption of Okmok in 43 BC, to investigate the climate forcing potential of these eruptions.

The Youngest Toba Tuff (YTT) supereruption (74,000 years ago) and its effects on the Indian Monsoon

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The global environmental impact of the YTT supereruption ~74 ka remains unclear, ranging from having negligible climatic effects to shaping the evolution of modern humans. Climate models and terrestrial proxy records suggest a significant cooling of the Asian landmass after the YTT supereruption that might have affected regional climate such as the Indian monsoon system. However, the immediate effect of the eruption on the Indian monsoon system has not been indisputably demonstrated in proxy records such as marine sediments. Here, we present a nearly annually resolved phytoplankton-based primary productivity (PP) record from laminated sediments in the northeastern Arabian Sea that shows a ~65% increase in PP for about 10–20 years directly after the eruption. This PP increase is best explained by elevated nutrients in surface waters caused by a deepening of the ocean mixed layer due to strengthened northeasterly Indian winter monsoon winds. Stronger Indian winter monsoon winds might have been the result of an increased north-south air pressure gradient caused by cooling of the Asian landmass right after the YTT supereruption. This interpretation is independently supported by previous modeling studies and demonstrates strong evidence for an Indian monsoon response to the YTT supereruption, potentially impacting also the northwestern Indian Ocean. Intensified northeasterly winds must have decreased the PP in the upwelling region off Somalia, similar to modern observations during winter. Consequently, the marine food supply of early humans in that region might have been significantly reduced after the YTT—a factor that potentially contributed to the timing of the postulated early human migration window during this time.

Regional monsoon sensitivity to Pinatubo-like volcanic eruptions of different sulfur emission strengths

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The impact of volcanic forcing on tropical precipitation is investigated in a new set of sensitivity experiments within the Max Planck Institute Grand Ensemble framework. Five ensembles are created, each containing 100 realizations for an idealized 'Pinatubo-like' equatorial volcanic eruption with emissions covering a range of 2.5-40 Tg sulfur (S). The ensembles provide an excellent database to disentangle the influence of volcanic forcing on monsoons and tropical hydroclimate over the wide spectrum of the climate's internal variability. Monsoons are generally weaker for two years after volcanic eruption and their weakening is a function of emissions. However, only a stronger than Pinatubo-like eruption (~10 Tg S) leads to significant and substantial monsoon changes, and some regions (such as North and South Africa, South America and South Asia) are much more sensitive to this kind of forcing than the others. The decreased monsoon precipitation is strongly tied to the weakening of the regional tropical overturning. The reduced atmospheric net energy input and increased gross moist stability at the Hadley circulation updraft due to the equatorial volcanic eruption, require a slowdown of the circulation as a consequence of less moist static energy exported away from the intertropical convergence zone.

Constraining the climatic impacts and season of occurence of the Mazama Ash: insights from laminated marine sediments from the NE Pacific

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Tephra deposits from the cataclysmic eruption of Mt Mazama, Oregon at ca. 6,730 ^{14}C yr BP have been widely reported in sediment records from the western United States and southwestern Canada, and the ash layer represents one of the most important stratigraphic markers for the mid-Holocene in western North America. In spite of a substantial literature on the ash, there remain uncertainties about the character and distribution of the tephra fall-out and the climatic impacts of the ash. In this paper we present the results of a very high-resolution study of a diatomaceous marine sediment core (MD02-2494) from Effingham Inlet, SW Vancouver Island, British Columbia, spanning the interval of the ash. The sediments were deposited under anoxic conditions, are well laminated and preserve a seasonal to sub-seasonal record of primary productivity change, permitting clear delineation of the season of tephra deposition. Scanning Electron Micrographs reveal that the lower boundary of the ash is sharp, suggesting sudden inundation and highlighting a lack of bioturbation and sediment reworking. The ash was deposited as a discrete unit, with little interspersed within it except for some *Chaetoceros affinis* resting spores and *Chaetoceros* vegetative cells. This indicates that the ash was deposited en masse rather than gradually or in stages. The volume of ash in the core suggests that the ash likely restricted light availability in the water column and temporarily suppressed primary productivity until it descended through the photic zone. Thin section analysis of diatomaceous sediments spanning a ca. 30 year interval around the ash further confirm that prior to the ash-fall, climate was characterized by warm, dry conditions with significant autumn productivity. However, increased precipitation and enhanced pelagic intrusion into the inlet are inferred around the time of the ash fall, possibly as a result of storm activity associated with high volumes of ash in the atmosphere. These conditions were sustained beyond the impact of the eruption. The presence of the Mazama ash in Effingham Inlet has redefined the known boundaries of the ash-fall in the NE Pacific region, which has not previously been documented this far northwest of the source.

Volcanic glass from the 1.8 ka Taupō eruption, New Zealand, in Antarctic ice: implications for eruption timing, impact assessments and ice core chronologies

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Geochemical analyses of microscopic volcanic glass shards (5–30 µm long) extracted between 278.822 to 278.866 m depth from an interval of the Roosevelt Island ice core (RICE), eastern Ross Sea, Antarctica, associated with increased non‐sea‐salt conductivity and insoluble particle count measurements at 230 ± 32 CE indicate that two chemically distinct populations of trachytic and rhyolitic glass are present and derived from explosive eruptions of Mt. Melbourne, Northern Victoria Land, Antarctica and Taupō volcano, New Zealand, respectively. Unpolished scanning electron microscopy analysis using energy dispersive spectrometry (SEM‐EDS) and polished electron microprobe analysis using wavelength dispersive spectrometry (EMPA‐WDS) were conducted due to the low number and small size of analysable particles. Recognition of tephric material from the independently‐dated 232 ± 10 CE Taupō eruption for the first time in Antarctica provides valuable links to mid‐latitude terrestrial and marine palaeoenvironmental and palaeoclimatic records in widely different geographic areas and depositional environments. These links can aid reconstructions of volcanic impacts on climate, offer insights into the ash cloud extent, dispersal and long‐distance transport of tephra in the Southern Hemisphere, and will help to correlate between and constrain the age of existing ice core and blue ice chronologies in Antarctica.

The Possible Climatic and Societal Impacts of Volcanic Eruptions in the Former Han Dynasty (202 BC- 8 AD)

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The climate history of China is well-documented, and the sufficient written records allow scholars from multiple disciplines to reconstruct the climatic characteristics of different times. The Former Han dynasty (202 BC- 8 AD) experienced several periods of climatic anomalies, and the society was profoundly influenced by the perceptions of environmental changes, especially philosopher Dong Zhongshu's "ominous politics". This presentation selects two historical periods, 180-150 BC and 60-30 BC, in order to explore the climatic stresses and atmospheric optical anomalies that were possibly related to volcanic activities, as well as how society was impacted and responded to such consecutive natural disasters in these periods. It examines the possible association between these climatic anomalies and volcanic eruptions by comparing evidence from historical sources to natural archives. For example, in 43 BC, when the Okmok volcano in Alaska erupted, the pale sun and cold summer were recorded in China, and the Empire suffered continuous floods, famines and plagues since the 40BCs. Similar climatic phenomena also happened in the 160BCs, in which, three large volcanic eruptions were documented by evidence from natural proxies, such as ice-cores. Furthermore, while most scholars employ quantitative methods to portray climatic and societal changes over a long span of time, the selection of the decade before, during and after climatic anomalies allows detailed assessments of the reliability of each written historical record. This research aims to evaluate the climatic and societal stresses by categorizing and quantifying relevant historical data. It will reconstruct how the Former Han society was impacted and gradually restored societal, economic and political stability. Building on this, a comparative analysis of the two historical periods will be conducted. The period 60-30BC inherited the political legacy from the period 180- 150 BC, but significant changes took place in various aspects, such as state governing and the understanding of natural disasters. Thus, by comparing the societal responses to calamities of these two periods, we can examine whether such changes were effective in terms of disaster prevention and mitigation, thereby identifying factors that may contribute to better resilience to drastic environmental changes.

Reconsidering the Egyptian ‘Famine Stela’ in light of volcanically-induced climate forcing in the 160s BCE

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The inscription of the so-called ‘Famine Stela’, carved into rock on Sehel Island in Egypt, describes a time when the Nile River failed to flood for seven years, leaving its banks unfertilised and barren, and afflicting the people with a catastrophic famine. Although presented as a monument left by an ancient king, the text was carved in the Ptolemaic period and is usually attributed to the reign of Ptolemy V Epiphanes (r. 205-180 BCE). However, an alternative possibility is that the stela dates to his successor Ptolemy VI Philometor (r. 180-145 BCE) and should be reconsidered in the light of an entirely different set of circumstances. Recent refinements to the dating of volcanic eruptions in antiquity and new research on their climate forcing effects, particularly on Nile flood suppression and disruption to rainfall patterns, identifies an extended period of environmental instability in the 160s BCE. It is argued that the circumstances of this decade, in which a trio of significant volcanic events precipitated low temperatures, unseasonal rainfall, poor Nile flooding and repeated crop failures, catalysed a prolonged food crisis – and that this time provides a more likely context than earlier, demonstrably less volatile periods, for the preoccupations of the authors of the Famine Stela. That text may now be reassessed as a response to the famine that afflicted the First Cataract of the Nile in the mid-second century BCE.

Climatic and societal impacts in Scandinavia following the 536/540 CE volcanic double event

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In the Northern Hemisphere, the mid-6th century was one of the coldest periods of the last 2000 years, which was initiated by volcanic eruptions in 536 CE and 540 CE. Here, we study the effect of this volcanic double event on the climate and society in Scandinavia with a special focus on Southern Norway. Running an ensemble of Max Planck Institute ESM transient simulations for 521-680 CE based on the PMIP4 past2k set-up, temperature, precipitation and atmospheric circulation patterns are analysed. The simulated cooling magnitude is used as input for a growing degree-day (GDD) model for different study areas in Southern Norway, representative of typical meteorological and landscape conditions. Pollen from lake sediments and peat bogs inside these study areas are analysed at high resolution (1-3 cm sample intervals) to give insights into the validity of the GDD model set-up with regard to the volcanic climate impact on the regional scale, and to link the different data sets with the archaeology records. We find that after the 536/540 CE double event, a maximum surface air cooling of up to 3.5 °C during the mean growing season is simulated locally for Southern Norway. With a worst-case regionally averaged scenario cooling of 3 °C, the GDD model indicates crop failures in our northernmost and western study areas, while crops were more likely to mature in the southeastern study area. These results are in agreement with the pollen records from the respective areas. Archaeological excavations show, however, a more complex pattern for these areas with abandonment of farms, severe social impact but also a continuation of occupation or a mix of those. Finally, we discuss the likely climatic and societal impacts of the 536/540 CE volcanic double event by synthesising our new and available data sets for whole Scandinavia.

Session 121: The anthropology of climate change

Modelling human responses to past climate change

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In this presentation I will provide an overview of the main numerical modelling methods used to simulate human responses to past climate change. These include:

1) eco-geographic species distribution models, which link archaeological and anthropological data of human remains with paleo-climatic information to derive patio-temporal estimates of habitat suitability.

2) density-based models to describe human dispersal and multi-species interactions. Such models are usually based on reaction-diffusion partial differential equations equations, with empirically constrained demographic and dispersal parameters and are used to study human migration and competition with other groups.

3) Agent-based models, which capture the dynamics of individuals in a time-varying climatic environment through specific rules. These models have the advantage that cultural and genetic factors can be explicitly included and simulated.

For each of these methods, I will introduce one realistic example to highlight their capability in informing us on species interactions, origins and speciation events and to demonstrate their overall advantages and disadvantages. The presentation concludes with a discussion on how these methods can be combined to obtain more realistic estimates of predator-prey relationships and of carrying capacity.

Effects of glacial climate on hominin habitat overlap and gene flow

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Archaic human admixture has played a critical role in shaping the genomic ancestry of modern humans, leaving a legacy even in our present-day population. When, where, and how often hominin interbreeding happened, nevertheless, is largely unknown. In this study, we combined extensive fossil, archaeological, and genetic data with transient Pleistocene climate and biome simulations to determine how orbital-scale climate shifts affected the level of introgression between Denisovans and Neanderthals. Specifically, we developed and applied two species distribution models to predict the habitat suitability for Denisovans and Neanderthals at every location and time during the past 400,000 years, as well as the level of habitat encroachment - a proxy for population/genetic introgression. Our analyses revealed that glacial/interglacial changes in atmospheric CO2 concentrations caused large-scale shifts in temperature and vegetation across Eurasia, which controlled where and when these two hominin groups lived, overlapped, and interbred. Finally, we will show our most recent findings from a density-based dispersal/interaction model, which can quantitively simulate the spatiotemporal change of the two-hominin admixture during last 2 glacial cycles.

And yet, they had to start somewhere. A new method to find the area of origin of past Homo species

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The area of origin (AOO) of past *Homo* species is a hotly debated, yet poorly resolved issue in paleoanthropology. Aside from naming issues, sister species relationships between pairs of lineages are well-established (e.g. *Homo heidelbergensis* and *Homo sapiens* in Africa, *Homo neanderthalensis* and Denisovans in Eurasia). Yet, the AOO of these species pairs is obscure, and the environmental conditions that set apart the two species in the pair are little investigated (but see Raia *et al.* 2020; Timmermann *et al.* 2022). We developed a new method, named *RRphylogeography*, that takes advantage of species distribution modeling, and from phylogenetic reconstructions of trait evolution to estimate the best-suited, most probable AOO for any species pairs. Applied to the record of *Homo*, *RRphylogeography* suggests a Central European origin for the split between Denisovans and Neanderthals. Although surprising, this AOO is consistent with the extra-African distribution of *Homo heidelbergensis*, which should have been ancestral to the pair. The split between *H. heidelbergensis* and us is not unambiguous. Three areas, East Africa, South Africa and the Western Maghreb are suitable AOOs for *H. sapiens,* supporting the idea of a geographically structured archaic metapopulation (Scerri et al. 2019). How much each region contributed to the speciation process into *Homo sapiens* and whether the transition from archaic to modern traits emerged in one or in different regions, sequentially or in parallel (Meneganzin *et al.* 2022) remains elusive.

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A comparative study of climate resilience in Neanderthals and H. sapiens

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The permanent settlement of Western Eurasia by *Homo sapiens* during the Late Pleistocene coincides with the gradual decline and eventual disappearance of the Neanderthals. Whether the Neanderthals were driven to extinction by unstable climate conditions, competitive exclusion, or a combination of the two has been hotly debated since the last century. Our understanding of the process of population replacement in Europe has been revolutionized by new archaeological discoveries, improved chronology, advances in paleogenetics, climate reconstruction and climate modelling. It is now generally accepted that Neanderthals and *H. sapiens* co-existed in Eurasia for several thousand years, interbred successfully, possessed similar cognitive abilities, demonstrated complex social skills and adapted to climate change through technological and social innovation. Why then did Neanderthals become extinct? The co-existence of Neanderthals and *H. sapiens* in Europe during MIS 3 provides a unique opportunity to compare the resilience of two recent hominin species in a context of rapid climate change in an attempt to answer this question.

Winter driven seasonality changes during Dansgaard-Oeschger cycles: potential impact on human populations in Western Europe during MIS 3

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Marine isotope stage 3 (MIS 3) (~60-30 ka) exhibited large-amplitude millennial climatic oscillations that were particularly pronounced in the North Atlantic region. Referred to as the Dansgaard-Oeschger (D-O) cycles, these alternations of warm (GI – Greenland Interstadials) and cold phases (GS – Greenland Stadials) likely impacted human populations of Western Europe by modifying the distribution of resources upon which they depended. To understand this impact, we explored the nature of the D-O cycle climate signal in Western Europe using 18 pollen records that enabled the reconstruction of the vegetation and key climatic parameters such as seasonal temperatures and precipitation. Our results show a clear response of the vegetation to the climate changes associated with D-O cycles, with arboreal vegetation during warm phases and non-arboreal vegetation during cold phases. More importantly, our results demonstrate that the vegetation changes were mainly driven by shifts in winter temperatures and precipitation, with lower temperatures and precipitation during GS and vice versa, whereas summer conditions remained relatively stable throughout MIS 3. It has been demonstrated that during the LGM seasonal variability influenced long-term patterns of human habitat suitability. Our results suggest that the D-O cycles over Western Europe were mostly a winter phenomenon, likely related to the atmospheric circulation over the North Atlantic. Here we test the hypothesis that stronger seasonality during GSs altered the seasonal distribution of suitable habitat, forcing human populations to modify their spatial distribution, which ultimately influenced demographic patterns.

Changes in Climate extremes in Zambia during Green and Dry Sahara periods and their potential impacts on hominid dispersal

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Africa experienced orbitally forced climate cycles throughout the Pleistocene, when the African humid periods, or "Green Sahara" periods, alternated with dry periods. These climate cycles are thought to have influenced patterns of human dispersal on a continental scale. In this study, we use a regional climate model to simulate archetypal Green and Dry Sahara periods under high and low boreal summer insolation to investigate changes in climate variability and extremes with a focus on Central Africa. Our results suggest that Zambia provided better environmental conditions for hominin populations during the Dry Sahara periods than the Central African Plateau (CAP). On the other hand, the Green Sahara periods were relatively drier and hotter than the Dry Sahara periods over the Zambian region with an increase in the length of droughts and an intensification of temperature extremes. At this time, river valleys would have provided a refuge from arid conditions, channelling hominin dispersals into the CAP and northward into the Sahel and the Sahara.

Synthesizing climate model and proxy data with a spatio-temporal Gaussian Process

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A growing number of spatial and temporal high-resolution climate modelling products with regional and global coverage have fuelled the use of paleoclimatic data in all disciplines studying the Quaternary. Anthropologists examine hominin dispersal, demography or extinction with Species Distribution Models, archaeologists study cultural change in the light of climate, and geomorphologists feed Landscape Evolution Models with climate data. However, the choice of an appropriate product is not always made based on an objective assessment of different candidates, but rather based on availability through data portals, compatibility with research software, publication bias and researchers' subjective preferences. We present a method that combines a large number of published paleoclimate simulations, existing gridded reconstructions and proxy data to infer a consensus model and make the uncertainty of different data sources transparent.

Our setup for the timeframe between 21 ka and 6 ka BP in Europe reuses published data from 12 climate simulation snapshots of the Last Glacial Maximum (LGM) and the Mid-Holocene (MH), two continuous datasets with 1,000 year resolution that statistically combine simulations and non-European proxies, and a large compilation of pollen-based climate reconstructions for Europe. Climate-field reconstructions (CFRs) combine these datasets into a statistical spatial or spatiotemporal model. To date, there exists no consensus paleoclimate model that is continuous in space and time, produces predictions with uncertainty, and can include data from various sources. Our Gaussian process (GP) model has these desired properties; however, GPs scale unfavorably with data of the magnitude typical for building CFRs. We build on recent advances in sparse spatiotemporal GPs that reduce the computational burden by combining variational methods based on inducing variables with the state-space formulation of GPs. We successfully employ such a doubly sparse GP to construct a probabilistic model of European paleoclimate from the LGM to the MH that synthesizes paleoclimate simulations and pollen data.

In the future, we aim to extend this method to global coverage and longer time-periods. Our product is targeted at researchers from diverse fields, who (a) request consensus paleoclimate estimates for certain points in space and time that (b) make the degree of agreement between various sources transparent.

Session 123: Advances in tectonic geomorphology, paleoseismology, and multi-disciplinary active fault studies

Timescales of intraplate surface rupture preservation from modeling and the landscape record

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Large surface-rupturing continental intraplate earthquakes are uncommon globally and are thought to have recurrence intervals of thousands to hundreds of thousands of years based on the paleoseismic and geomorphic record. However, the preservation of surface ruptures is impacted by several variables, such as climate, depth and/or magnitude of the earthquake, frequency of surface-rupturing events, anthropogenic modification, and pre-existing topography or geomorphology, resulting in biased or inaccurate estimates of recurrence intervals and hazard from the landscape record alone. In this study, we take a two-pronged approach to better understand how surface ruptures of primarily dip-slip events may be preserved in intraplate settings. First, we use a two-dimensional (2D) scarp diffusion model for typical intraplate settings and explore different parameters influencing the creation and erosion of surface-rupturing features. These parameters include the initial magnitude of surface rupture vertical offset (likely related to the depth and magnitude of faulting), climate (using diffusion rate as a proxy for precipitation), and recurrence interval of similar magnitude events. Second, we compile and evaluate historical and paleoseismic evidence of surface ruptures in intraplate settings in a variety of climates, such as the Central and Eastern United States, Australia, Europe, Central Asia (Mongolia, China), India, and West Africa, to compare with the diffusion modeling results. The historical and prehistoric earthquakes in these regions have different fault kinematics and earthquake depths and magnitudes, allowing for a spread of examples to compare the influence of different parameters in the diffusion modeling. This study highlights the variable degrees of preservation in different intraplate settings and the implications for interpreting the seismic hazard of a region based on the limited geomorphic record.

Long- and short-term surface deformation and seismotectonic framework of the Mw 7.7 2001 Bhuj earthquake epicentral area (Gujarat, NW India)

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The Mw 7.7 (source USGS), 26 January 2001 Bhuj earthquake (23.4 ° N, 70.3 ° E) was the largest intraplate earthquake occurred in the current century and, in spite of its magnitude, was characterized by the lack of clear evidence of primary surface faulting. Based on the seismological record, the event occurred along a roughly east-west reverse fault in the Kachchh region of NW India, a low strain rate pericratonic rift basin hit by large earthquakes having long recurrence time (e.g., the Mw 7.8, 1818 Allah Bund and the Mw 6.1, 1956 Anjar earthquakes), where the climatic and tectonic forcings rival in controlling the landscape evolution. However, the long-term prevalence of the tectonic forcing is testified by occurrence of fault-bounded high topography areas, such as the Kachchh, Wagad and Island Belt uplands, surrounded by the near flat topography of the Banni plain salt marsh, part of the Great Rann of Kutch.

The 2001 seismic event was widely studied in the past two decades using SAR, remote sensing, post-seismic field surveys and paleoseismological investigations, however the seismogenic sources and the seismotectonic framework of the area are not firmly established. Indeed, due to their poor morphological signature and the few subsurface geophysical data available, the geometrical and kinematic parameters of many of the active structures recognized in the field are still controversial.

To provide new constraints to the seismotectonic characterization of the area, following a critical review of the literature, we propose a multidisciplinary approach to investigate both the long-term and the short-term surface deformation induced by the active faults, including the 2001 seismogenic source, that force the evolution of the landscape.

We studied the long-term deformation (from Kyr to a few Ma) through morphometric analysis of the main drainage patterns and relief distribution. In addition, we investigated the short-term deformation (from years to two decades) through InSar analyses.

We present a proposal of location and geometrical and kinematic characterization of the active faults driving the recent geological evolution, thus improving the understanding of the seismotectonic framework of an area that hosted one of the deadliest intraplate earthquakes ever recorded.

The Børglum fault, Sorgenfrei-Tornquist Zone, northern Denmark: a multi-method approach reveals fault kinematics, timing of fault activity and paleo-earthquake magnitude

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Faults in low-strain intraplate areas can be the source of unexpected and fatal earthquakes, because of the long intervals between individual seismic events and the fact that such faults are often covered by young sediment, which makes fault detection difficult. We present a multi-method approach based on outcrop analyses, shear-wave seismic reflection surveys, DEM analyses and numerical simulations that focuses on the Børglum fault in northern Denmark, which represents one of the northern boundary faults of the Sorgenfrei-Tornquist Zone. Previous studies showed evidence that the Børglum fault is seismically active and with a length of at least 250 km, it is capable to produce significant seismic events. This fuelled the demand for further analyses of the fault structure and its seismic hazard potential. Two shear-wave reflection seismic surveys were acquired to image the near-surface structure in the vicinity of the Børglum fault. The seismic surveys indicate that the Børglum fault is not an isolated fault, but most likely represents a complex fault system with a strike-slip component. Positive flower structures on the seismic surveys, the presence of elongated mini-basins and the geometry of the drainage pattern in the study area support a strike-slip interpretation. The seismic surveys indicate that faults in the study area were probably active at the end of the Saalian glaciation (MIS 6). Furthermore, soft-sediment deformation structures and disaggregation bands developed in Late Pleniglacial to Lateglacial sediments point to repeated phases of fault activity with earthquakes magnitudes of up to M=7. The reflector pattern on one of the seismic surveys indicates that a major fault of the Børglum fault system in the study area nearly reaches the Earth's surface. A step in the topography above the fault probably represents a fault-scarp. Together with the geometry of the drainage pattern, this implies a close relationship between fault activity and topography in this region. The timing of fault activity and numerical simulations of deglaciation-related lithospheric stress build-up indicate that the Børglum fault is a glacially triggered fault and that this part of the Sorgenfrei-Tornquist Zone can be interpreted as susceptible to glacially triggered fault reactivation.

Neotectonics and fault segmentation of the Ulsan fault and Yeonil tectonic line, SE Korea

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The Korean Peninsula which is located far from the plate boundary has been regarded as a relatively stable region compared with the plate boundary in terms of earthquakes. However, the recent two moderate earthquakes (the 2016 M_w 5.5 Gyeongju earthquake, and the 2017 M_w 5.4 Pohang earthquake) that occurred on the Korean Peninsula have triggered a change in the national perception of earthquakes. Since these earthquakes occurred adjacent Yangsan and Ulsan faults located in the southeastern part of the Korean Peninsula, the demand for paleoseismological research on these faults has increased.

The Ulsan fault zone is NNW-SSE trending reverse dominant fault with a length of approximately 60 km from Ulsan to Gyeongju city in the southeast Korean Peninsula. The Ulsan fault zone was presumed based on the clearly recognized fault valley on the map, geomorphological characteristics related to the uplift of the eastern mountain range, and geophysical survey. However, direct evidence of the Quaternary reactivation of the Ulsan fault through surface geological surveys is insufficient due to the thick sediment layers which covered the urbanized area. Meanwhile, several active faults have been reported along the Yeonil Tectonic line which is located approximately 4-5 km east of the Ulsan fault. It is necessary to understand uniform faults through fault segmentation as well as geometric-kinematic correlations to interpret the spatio-temporal history of a series of fault systems. In this study, we consider not only the geometric segmentation but also the paleoseismic parameters (slip rate, recurrence interval, etc.) along the Ulsan fault zone. Furthermore, a more systematic fault segmentation is attempted through the quantification of each component by reflecting all of the kinematic fault behavior, structural characteristics, and especially geomorphological characteristics of the mountain front range.

An automatic approach to estimate earthquake chronologies from paleoseismic fault records

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Earthquake occurrence estimates along active faults are crucial for fault-based seismic hazard assessments. Hence the use of paleoseismic datasets has become increasingly relevant for fault characterization, especially in regions where the catalogues are too short to capture their longer seismic cycles. One of the main challenges in paleoseismic research though is to objectively correlate data from multiple sites along a fault and thus, to establish reliable paleoearthquake chronologies. Several issues including large dating uncertainties, poor stratigraphic resolution/preservation and fault offset variability along strike can cause this. Subsequently, these eventually hinder the detection of paleoearthquakes and increase the uncertainties in their time constraints.

We present a new approach to derive paleoearthquake chronologies in faults by means of multi-site correlation of paleoseismic trench data and statistical modelling for a proper treatment of the uncertainties. The approach seeks to maximize objectivity in the whole procedure and for this reason, it strictly relies on the numerical dates limiting event horizons in trenches as inputs. From these data and using an automatic algorithm, all event occurrences in each site are modelled as probability density functions (PDFs) and then correlated by computing a product curve that represents the overall fault occurrence probability. The peaks in this product curve are extracted as final PDFs and interpreted as the earthquake chronology of the whole fault. In contrast with other approaches, the correlation process is not restricted to individual events. Instead, an event in one site can participate to the correlation with more than one event in another site if their time ranges overlap. This allows to accommodate into the approach the inherent event underdetection problem of paleoseismology, especially when uncertainties in event timing are large. The outputs of the workflow are simple and can be further used as inputs to calculate critical fault parameters (e.g., recurrence times).

The approach we present allows modelling the paleoearthquake history of faults from paleoseismic information, while constraining the uncertainties in event dating. Specifically, the approach can be useful in settings where the large event date uncertainties or number of sites prevent straightforward interpretations.

Geochemical (XRF) evidence of land-level change during the 1700 CE Earthquake at Cascadia using an ITRAX Core Scanner

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Along the Cascadia subduction zone, relative sea-level (RSL) reconstruction studies are critical for understanding coastal flooding risk because Cascadia has not experienced rupture during the instrumental period. Beneath tidal wetlands along Cascadia, coastal subsidence during successive, prehistoric earthquakes is commonly recorded by stratigraphic sequences of sharp (< 1 mm) mud-over-peat contacts. At Cascadia, the application of sedimentological and paleontological proxies to sediment cores with repeated mud-over-peat contacts have permitted the reconstruction of past land-level change during megathrust earthquakes. In this study, we explore how elemental analysis of sediment from tidal wetlands can be used to better understand coastal subsidence during successive, prehistoric Cascadia subduction zone earthquakes.

We apply X-ray fluorescence (XRF) analysis on two sediment cores, located ~ 1 km apart, from the lower and middle Niawiakum River, Willapa Bay, USA. Both cores contain a sharp, mud-over-peat contact which has been inferred to record subsidence during the 1700 CE Earthquake. The sediment cores were analyzed using an ITRAX Core Scanner at 100-μm resolution (30 kV; 55mA) using a molybdenum x-ray tube. Elements were measured in counts per second and normalized to the ratio of Compton to Rayleigh (incoherent/coherent) scattering. XRF measurements show differences in elemental concentrations between the underlying peat and overlying mud concurrent with land-level subsidence and the subsequent deposition of allochthonous marine sediments. In the lower and middle Niawiakum River sediment cores, the underlying peat show lower concentrations of silicon and titanium and higher concentrations of bromine. Across the mud-over-peat contact is a sudden shift to higher concentrations of silicon and titanium and lower concentrations of bromine in the overlying intertidal mud. Our results suggest that RSL reconstruction studies of land-level change caused by prehistoric megathrust earthquakes may be aided by XRF analysis, a rapid analytical technique that allows for higher resolution data points compared to other micropaleonotogical and sedimentological methods (100-μm vs. <1-cm).

High-Resolution seafloor quantitative morphologic analysis to characterise the growth of a transtensional system (North-South fault system, Alboran Sea)

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A better understanding of fault segment growth and interaction in seismically active regions improves our knowledge to asses the associated hazards. These may be more critical in areas that accommodate relatively slow tectonic deformation since they may enclose active faults capable of producing moderate to large earthquakes, despite the long recurrence intervals between events (10^3 to 10^4 years). An example is the Alboran Sea, a Neogene basin located in the Westernmost Mediterranean Sea that absorbs part of the convergence between the Eurasian and Nubian plates (3 - 5 mm/year). Currently, it is characterised by slow tectonic deformation and low to moderate-magnitude earthquakes. However, large historical and instrumental events have also occurred (i.e., the Almeria 1522 IEMS98 VIII-IX or the Al-Idrissi 2016 Mw 6.4 earthquakes). Our objective is to characterize the seafloor geomorphology produced by the Plio-Quaternary activity of the North-South faults, in order to discuss the system growth and evolution, and the regional kinematics. To this aim, we have analysed the area using different morphologic approaches and an ultra-high-resolution bathymetry dataset (1 meter resolution). Firstly, we have performed different relief visualisation techniques to map the faults' trace. Secondly, we have applied quantitative morphometric methods to estimate the scarp morphological parameters for each fault, with special emphasis on their height. Parallel and perpendicular swath profiles have provided the information to classify the fault scarps in different groups according to their magnitude and to analyse the distribution and relations between the different fault segments. Then, bathymetric profiles across the fault scarps have been used to accurately evaluate the variations on the height of the scarps along the different fault segments. In addition, we plan to improve our faults trace segments analysis by using semi-automated algorithms and neural network models on our dataset. Initial findings reveal several fault scarps striking N-S, resulting in horst and graben systems, as well as large fault segmentation and small accumulated fault displacements. Our results, suggest that the area is in an initial stage of evolution and related to the development of a transtensive left-lateral shear zone.

Construction of a multi-lake palaeosismometer for the Xianshuihe Fault (SE Tibet)

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Mountain lakes have been recognized as remarkable archives of seismic events globally. However, quantitative estimates of both palaeointensities and locations have not yet been obtained. Earthquake records in lake sediment depend on external (i.e., earthquake characteristics) and internal (e.g., sedimentation rate, basin geometry) factors. To evaluate paleo-earthquake characteristics, precise calibration of lake sensitivity with documented earthquakes is necessary to disentangle earthquake versus site-related parameters.
We tested this methodology on six small mountain lakes located along the active Xianshuihe fault system, SE Tibetan Plateau. Sediment cores collected in 2021 were dated with short-lived radionuclides and radiocarbon ages. We performed a multiproxy approach, including granulometry, loss-on-ignition, magnetic parameters, continuous XRF core scanning, and discrete quantitative measurements, XRD, and SEM for microfacies analyses. These observations allowed us to identify event deposits and validate their co-seismic origin, thanks to the Chinese seismic catalogs covering the last three centuries. We discuss how magnitude, rupture extent, and epicenter-lake distance control the trigger of event deposits at each site. Considering the calibrated site sensitivity, triangulating between several lakes where events are recorded provides a regional palaeosismometer yielding event's intensity and location.

Using lacustrine paleoshaking evidence to quantitatively determine earthquake source parameters

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Lacustrine paleoseismology has proven an invaluable tool to adequately reconstruct the seismic shaking history of a particular region, especially along subduction zones where the seismic hazard is multifold. One of the main strengths in such studies lies in the application of a multi-lake approach, in which spatio-temporal correlation of sedimentary shaking evidence allows distinguishing imprints related to large-scale megathrust earthquakes from those caused by locally intense intraplate shaking. Unfortunately, the relationship between local ground motions and earthquake source parameters such as magnitude and rupture location—both of which are crucial for adequate seismic hazard assessments—is usually inferred by considering qualitative rather than quantitative constraints. To overcome this drawback, we developed a methodology based on the principles of probabilistic seismic hazard assessment and ground motion modelling. To explain an observed spatial distribution of sedimentary shaking imprints (or the lack thereof) for a particular paleoearthquake, we infer the minimum and/or maximum shaking intensity that must have been achieved at each location. The probability that an earthquake with a specific magnitude in a certain location produces ground motion levels that fall within the range defined by these minimum and maximum thresholds is then calculated by application of a suitable intensity prediction equation (IPE) or ground motion prediction equation (GMPE). To illustrate these concepts, we present a case study from a ~4400 year old earthquake, identified in the Chilean Andes in the sediments of Lago Castor and Pollux as well as in Aysén Fjord. The methodology has thus been successfully applied to crustal earthquakes, for which fault geometry, morphology and length are well-constrained and rupture variability is limited. In the near future, we aim to apply the same principles to megathrust earthquakes by also taking into account variability in, for example, rupture depth, length, directivity and slip distribution.

Multi-disciplinary approaches in Lake Iznik (NW Turkey): new insights into past large earthquakes.

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In Turkey, the North Anatolian Fault (NAF), accommodating the westward movement of Anatolia with respect to Eurasia, is one of the most active faults in the world. A series of earthquakes (M>6.8) have propagated from east to west during the last century. The next rupture seems to be expected in the Marmara region, south of Istanbul. However, the geometry of this fault becomes more complex in this region. It splits into three branches, one of which borders the southern Marmara Sea and Lake Iznik. This median segment of the NAF (MNAF) has very low seismicity today, and low displacements are recorded by GPS, which leads to considering it inactive. However, the city of Iznik, the cradle of Christianity, has preserved valuable historical evidence in contrast to its observations. To better understand the seismic hazard in this area, it is necessary to catalogue the seismic activity and locate past ruptures.

Our work led to identified two active faults after different geophysical and coring campaigns in Lake Iznik. The study of short (<4m) sediment cores sampled on both sides of the E-W fault passing near Iznik city shows that the last rupture, dating from 1065 CE, corresponds to a devastating historical earthquake documented in the archaeological buildings of the city. In addition to this localised rupture, numerous other event deposits are present in the sediments (laterally and temporally). We showed that different types of deposits are sometimes recorded for the same earthquake and that one type of deposition is only observed for the 1065 CE earthquake, which takes place in the lake, unlike the others, suggesting that this type of deposition may depend on ground motion parameters besides the source-core distance.

We also compiled marine and lacustrine palaeoseismological studies carried out at the scale of the western part of the NAF. We show that the relationship between sedimentation rate and the onset of earthquake-induced slope destabilization does not work in the marine environment, unlike in the lacustrine environment. We also show that Lake Iznik records earthquakes from the NNAF and the MNAF, whereas the Sea of Marmara records only NNAF earthquakes.

The paleoseimological potential of large tectonic lakes on Sulawesi, Indonesia

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The Island of Sulawesi, in eastern Indonesia, is located at the triple junction of the Australian, Pacific and Eurasian tectonic plates. The stress between these plates is released through earthquakes, especially along the Palu-Koro Fault, crossing the island from northwest to southeast, as documented with the 2018 Mag. 7.5 Palu earthquake. Past major earthquakes are poorly documented on the island. A recent study on Lake Towuti shows more abundant turbidite deposits during the Last Glacial Maximum. But this single study site does not provide evidence of necessarily more intense tectonic activity as climate also appears to control the occurrence of event-driven deposits. We suggest climate strongly influences the sensitivity of slopes to fail during seismic shaking in this tropical setting as a consequence of lowstand-forced sediment redeposition Climate-controlled lake-level fluctuations substantially alter the sensitivity of Lake Towuti to be impacted by mass wasting. To better understand how climate and earthquakes interact in generating mass wasting, we compare two different study sites and their record of event deposits. Lake Poso, in central Sulawesi, is located ~50 km to the east of the Palu-Koro Fault and potentially an ideal site to document seismic activity related to this major fault system. Poso's sensitivity is underlined by documented nearby recent earthquakes, some of them occurring even along its longitudinal axis. Further factors strengthening the paleoseismic potential of the lake include assumed steep subaquatic slopes, sufficient sediment input from major inflowing rivers, and shoreline features favouring sediment destabilization to generate mass movements. A complete geophysical survey, combined with sediment coring, will allow to unravel the Late Quaternary evolution of Lake Poso and will help to understand the climatic and tectonic forces that control sedimentation in this understudied setting.

Lake paleoseismology in the Eastern Alps: from historical earthquake calibration to testing seismic hazard curves and analyzing rockslide triggers

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In intraplate regions, long-term reconstruction of earthquake occurrence provides important data for informing and testing hazard assessments. We have studied lakes in Carinthia and Tyrol (Austria) combining multibeam bathymetry, reflection seismics, sedimentology and geochemical techniques to establish 14-16 ka long records of past seismic shaking by analyzing subaqueous landslides, turbidites and in-situ sediment deformations. Age-depth models incorporate annual lamination counting and radio-isotopes (^{14}C, ^{210}Pb, ^{137}Cs). Based on the sedimentary imprint of historically-documented earthquakes (EMS-98 Intensity of V to IX at the lakes) we derived (i) seismic intensity thresholds for sedimentary imprints in different lake basins and (ii) scaling relationships between sedimentary parameters and seismic intensity. These ground motion indicators have then been applied to the prehistoric lacustrine sediment records.

In Carinthia, the sedimentary archive of Wörthersee recorded 44 earthquakes of intensity ≥V (max. IX). Recurrence statistics reveals the following: (1) Poissonian earthquake recurrence, as used in the probabilistic seismic hazard assessment, is confirmed for the last 2,800 years; (2) the current seismic hazard curves of the study area agree with the lacustrine paleoseismic record; (3) episodes of enhanced earthquake frequency can occur and need to be considered in seismic hazard analysis; (4) the last ~800 years show relatively many high-intensity events, with the 1348 CE earthquake producing the largest imprint of all Holocene events.

In Tyrol, 25 severe earthquakes are recorded in lakes Plansee, Piburgersee, and Achensee, from which four left imprints in two or more lakes. Earthquake recurrence intervals range from ca. 1,000 to 2,000 years. Plausible epicenters and magnitude estimates were derived by a reverse application of an empirical intensity prediction equation showing that paleo-earthquakes with a minimum M_W 5.8-6.1 might have occurred that were larger than known historical events. Temporal and spatial coincidence of paleoseismic evidence with multiple large rockslides at ~4.1 and ~3.0 ka BP reveals that such severe earthquakes are a key mechanism for major rock slope instability in the Eastern Alps. At Achensee, seismic profiles show coseismic surface rupture of a lake-crossing thrust at □8.3 ka BP and twice during late Glacial times.

Earthquake, gravity, or glacier? Deciphering deformation mechanism in Quaternary deposits along Idrija Fault in formerly glaciated Soča Valley, southeastern Alps

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In a highly dynamic environment such as the Alps, the study of active faults is often challenging because of the interaction between different processes that shape the surface. Different processes can deform Quaternary sediments in similar ways, but because of the associated geohazards, interpretation of deformation mechanisms can have a major impact on society. In such environments, it is even more important to use a variety of methods to study active faults and distinguish between different deformation mechanisms in Quaternary sediments.

We studied deformation structures in Late Quaternary sedimentary succession located on the slopes of the formerly glaciated Soča Valley in an ice-marginal area of Most na Soči and within the deformation zone of the Idrija Fault, a large, active, dextral strike-slip fault, one of the most important seismic sources in the area. Landforms, sediments, and deformation structures were studied through integrated geomorphological, sedimentological, and structural geological mapping using photogrammetric and leveling surveys, paleoseismological techniques, optically stimulated luminescence dating, and ground penetrating radar surveys. The succession consists of glaciofluvial, glaciolacustrine, glacial, and slope deposits from the Penultimate Glaciation and the Last Glacial Maximum. The older glaciofluvial succession is tilted and cut by a series of faults and joints, and the glaciolacustrine strata also show soft-sediment deformation.

Because of the local geologic setting, several possible deformation mechanisms had to be considered: glaciotectonics, gravitational faulting due to ice-decay or slope instability, and paleoseismic activity. After a detailed structural analysis, we interpreted some deformations as secondary structures resulting from repeated paleoseismic activity of the Idrija Fault during the deposition of the succession dated to the Penultimate Glaciation, as well as some structures resulting from glaciotectonics and gravitational faulting. The transtensional nature of the deformations at the studied site indicates the local character of the Idrija Fault, which can be explained by a local releasing bend. The complexity of the fault and the first paleoseismic evidence from the Penultimate Glaciation provide valuable new data for understanding the seismic hazard of this regional fault.

New insights into the active tectonics of the Eastern Southern Alps

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The northward motion and counterclockwise rotation of the Adriatic Plate leads to crustal deformation in the Southern Alps. Many aspects of this deformation, especially in the hinterland of the Southern Alpine orogenic front, are still not well-understood, mainly owing to the very low convergence rates. Here we present new results from the Italy-Slovenia-Austria border region that help to better understand the localization (or the lack thereof) of tectonic deformation, the postglacial activity of large faults, and the patterns of seismicity. We combine tectonic geomorphology studies on high-resolution digital elevation models with the analysis of satellite imagery, field mapping, near-surface geophysics, geodesy, paleoseismology, and Quaternary dating techniques to understand the pattern of Late Quaternary tectonics. In Slovenia, deformation is taken up by a system of NW-SE striking right-lateral strike slip faults in a more than 60 km-wide shear zone. Some of these faults are long enough to produce earthquakes exceeding magnitude 7, however, there is neither historical nor geological evidence for this. Additionally, many smaller, <15 km long faults show postglacial activity and in general, the deformation is widely distributed. In Italy, most of the deformation is accommodated by thrusting at the South Alpine orogenic front and in the Friulian Plain. Historical reports prove that strong earthquakes (M>6) occurred in the interior of the mountain chain, but seismicity is comparably low. Geological evidence of fault activity is poor because sedimentation/erosion, including landslides and rockfalls, and anthropogenic imprint dominate the present-day landscape and outpace any tectonic signal. We found a similar picture in Austria, where geological evidence of active faulting is sparse, despite a record of strong historical earthquakes. New dating results from both deformed and undisturbed geomorphic markers allow us to place constraints on the maximum amount of deformation that is accommodated in southern Austria and on fault activity in Slovenia.

The discovery of a forgotten earthquake: paleoseismological and archeoseismological evidence of a Late Antiquity event in Como, Northern Italy.

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Italy has one of the most complete and accurate historical seismic catalogues in the world, which can be considered as complete for the last ca. 1000 years for Mw ≥ 6.5. Nonetheless, it is well known that ancient events (i.e., older than medieval times) can hardly be accurately recorded by historical sources and that the probability of incompleteness grows with age. In regions characterized by low deformation rates, such as the Po Plain, an exceedingly long earthquake recurrence interval could possibly imply a significant underestimation of the seismic hazard.

Natural records, conversely, can be effective in filling the apparent gap in seismicity for ancient times. Some of the best examples are reported in studies on lake sediments, potentially able to image lake floor faulting or, more frequently, record large earthquakes as eq-triggered landslides/turbidites. From previous studies, geological offshore evidence of a Late Antiquity event hitting Northern Italy has been reported in the Alpine Lakes, possibly indicating a source area in the Central or Southern Alps. A definitive consensus of this hypothesis was lacking and the supposed earthquake-triggering together its age remains questionable if age-depth models are flawed or if we consider that mass wasting events can also be triggered by climatic causes as well.

Additional constraints for a possible seismic triggering would ideally be furnished by onshore evidence that is less prone to concurrent triggering by other causes, and the consistency of both the evidence would provide an ideal integrated set of evidence for seismic triggering.

In this work, we present a suite of onshore evidence of an ancient earthquake that hit the city of Como during the Late-Antiquity. By means of an archeoseismological and paleoseismological approach, we discuss secondary earthquake-induced effects that provide tight chronological constraints to the event occurrence. A comparison with previously published but less-constrained evidence for the same event provides a new hypothesis on the possible location of the seismogenic source.

Quaternary landscape evolution as a proxy for characterizing the active tectonics in a low strain rate region (Northern Sicilian margin, Italy)

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The areas undergoing a tectonic deformation at 1 mm/yr or less are considered tectonically Low Strain Rate regions (LSRr) and are characterized by infrequent, but nonetheless potentially damaging sesimicity. The Landscape Evolution (LE) of these regions is principally driven by climate controlled surface processes, inducing erosion and sedimentation rates overwhelming the active faults morphological signature, thus causing their hidden geometry and hampering their identification and mapping. Such framework, that drives to the underestimation of the seismic hazard, induces the society to host valuable anthropogenic assets in these regions considering them relatively safe, increasing the exposition, or not urge to the earthquake preparedness, increasing vulnerability. For these reasons, the infrequent seismicity may cause significant losses in LSRr, and identifying active structures is one of the primary challenges for both the scientific community and modern societies.

This work proposes a multidisciplinary approach to detect active geological structures and their related deformation in such areas. We designed our approach to quantitatively study the offshore and onshore landscape and LE through a multidisciplinary morphotectonic, tectonostratigraphic and GNSS joint analysis. To test this approach, we selected as LSRr natural laboratory the partially offshore northern Sicilian margin (southern Italy), in the coastal sector located between the two major cities of Palermo and Termini Imerese. This area includes the compressional structures of the northern sector of the Apennine-Maghrebian fold and thrust belt, presently accommodating the slow Africa-Europe plate convergence.

The main results we achieved are:

1. new evidence of active tectonic deformation in this region;
2. the 3D modelling of two NNW-trending active faults;
3. the slip rate of a segment of the westernmost of the two detected faults;
4. the redefinition of the coastal uplift rates;
5. a newly recorded relative GNSS velocity field for the study area;
6. a new morphotectonic map;
7. a new inland and coastal LE model of the study area.

Our multidisciplinary approach allowed us to shed new light on the active tectonic framework and created new opportunities for further studies on the long-term deformation of a slowly deforming area that crosses the physical limit of the coastline.

Glacially triggered faulting in a formerly glaciated intra-plate area: Consequences for Quaternary erosional patterns and the near-surface geological architecture

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Hypotheses about connections between deep-seated faults and the formation of erosional valleys in former glaciated areas have been suggested for more than a century. These hypotheses were typically based on large-scale topographic observations combined with sporadic subsurface data, but combinations of multiple datasets were generally not possible.

Around 25 years of buried tunnel-valley mapping in Denmark has resulted in three independent, nation-wide vector datasets: 1) Buried tunnel valleys, 2) Deep-seated faults (mapped in connection with oil and gas exploration surveys), and 3) Present-day topographic valleys. In order to systematically investigate to which extent faults may have impacted on the erosional patterns during the Quaternary, we have compared the three separate vector datasets with respect to orientations.

Several correlations in the datasets were observed. Correlations between the orientations of tunnel valleys and deep-seated faults suggested that structural weaknesses along faults have altered the hydraulic properties of the sedimentary strata and thereby created biased subglacial erosion patterns. However, correlations between deep-seated faults and erosional valleys in the present-day landscape, pointed to active tectonics allowing the erosion to reflect the tectonic framework in the topography. We thus propose a model that invokes the mechanism of glacially triggered faulting acting in all of the Danish area, causing an impact on the erosion patterns throughout the Quaternary. The erosion seems biased towards old, well-established patterns over active faults as these zones appear more susceptible to erosion. Our findings suggest that recurrent impact on erosion patterns from glacially triggered faulting can be expected in other areas in and around former glaciated areas.

Applying glacially triggered faulting to all of Denmark implies that deep faults may reach all the way to the terrain surface, and thereby guide and enhance erosion, but at the same time they impose disturbances on the sedimentary succession and the topography. The suggested model for the relationship between the tectonic framework and the erosion in former glaciated areas is therefore important for interpretations of geomorphology and the geological architecture. Several near-surface geological phenomena that have been difficult to explain using the traditional tool-box of glacial geology will now likely find alternative explanations.

What can uplifted, deformed Pleistocene palaeoshorelines tell us about long-term faulting offshore southwestern Crete?

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Coastal landforms such as palaeoshorelines provide a record of uplift associated with offshore faulting. However, in the forearcs of subduction zones where complex tectonic regimes dominate, compressional and extensional faults may be contemporaneously active. As such, the cause of palaeoshoreline uplift and deformation in subduction settings may not be clear, which confounds attempts to undertake effective seismic hazard assessment.

We undertake spatio-temporal analysis on sequences of Pleistocene palaeoshorelines in southwestern Crete where deformed Holocene marine notches are associated with coseismic uplift of up to 9 m from the 365 CE Mw >8 earthquake. Previous investigations into the Holocene notches have been used to infer that the dominant mechanism of uplift may be slip either on a reverse crustal fault or on the subduction interface. However, seismic reflection studies south of Crete infer the presence of numerous active offshore extensional faults whose role in long term deformation is unclear.

New ^{36}Cl exposure dating on Pleistocene wave-cut platforms and palaeoshoreline mapping in combination with existing age controls facilitates detailed interrogation of spatial uplift rate changes along a ~30 km E-W section of the coastline encompassing the uplifted 365 CE notch sites. We observe that the Late Quaternary uplift rates increase from west to east, a spatial uplift pattern that is inconsistent with published vertical deformation models of reverse faulting. These findings imply that other mechanisms of uplift may contribute to Late Quaternary palaeoshoreline deformation.

Elastic half-space dislocation modelling is used to interrogate the coseismic spatial uplift patterns expected to occur from slip on extensional offshore faults that are suggested to run parallel to the coastline of southwestern Crete. We use these coseismic uplift patterns as a proxy to examine the possible long-term (~400 ka) cumulative spatial uplift patterns that may occur due to extensional faulting. Our findings demonstrate at least one offshore extensional fault, with a minimum length of 28 km capable of producing Mw >6.5 earthquakes, may also contribute to uplift along southwestern Crete. Over Late Quaternary timescales, it may be that a combination of active extensional and compressional faults is responsible for uplift across the wider area of western Crete.

Active Fault Segments from Middle Strand of the North Anatolian Fault system, characterization and paleoseismicity, NW Turkey

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The Middle branch of the North Anatolian Fault (MNAF) forms part of the western termination of the dextral strike slip NAF system (Turkey). No recent earthquake was recorded on the MNAF in the last centuries contrary to the others active segments. 148 km of the MNAF were mapped using high resolution satellite imagery and field data. Offsets of landforms were systematically measured along 8 sub-segments of fault. Their statistical analysis shows coseismic lateral displacement of 3-6.5 m, that correspond to Mw~6.8-7.4 historical earthquakes able to propagate along several fault segments. Three segments bounded the Iznik Lake. Geophysical (bathymetric, seismic, Ground Penetration Radar) and paleolimnological studies (30 cores) were carried out in and around the Iznik Lake, to follow the structure of the MNAF in the lake and retrieved past earthquakes catalogue recorded by the lake sediments.

Two active fault segments were identified for the first time into the lake. The Iznik fault and the South Boyalica fault. The EW Iznik fault, is linear, parallel to the main dextral segment of the MNAF. It cross cut part of the lake and is connected on-land to the main fault segment. Several cores sampled from both part of the Iznik fault, associated to seismic data indicate that the fault has ruptured for the last time in 1065 CE with a vertical offset of 48 cm, we are still looking for markers horizontally offset.

The 1065 CE earthquake is recorded in all the cores of the lake. No earthquake was recorded after the 1065 in the Iznik sediments suggesting that it has totally purged the slopes of the lake. This earthquake has strongly damaged the Iznik city and destroy a famous basilica located on the shore. According to preliminary result, the penultimate earthquake on the Iznik Fault could be associated to the 368 CE historical earthquake; 7 centuries could have separated the two last earthquakes. The current seismic gap of 10 centuries on the Iznik Fault segment of the MNAF greatly increases the seismic hazard in this region showing that the MNAF must be considered in the seismic risk assessment of the NAF system.

Active shortening and prehistoric ruptures in basins of the central Tien Shan: insight from high-resolution DEMs and GPS velocity data

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Hundreds of kilometers north of the India and Eurasia collision front, the central Tien Shan accommodates around 20 mm/year of shortening across its ~400-km width. Late 19th to 20th century earthquakes with magnitudes of 7 to 8+ have been documented in the northern and southern sections of the mountain belt. In contrast, knowledge of such earthquakes occurring in interior basins did not exist until the recent advent of high-resolution remote sensing and better accessibility. In this study, we investigate the evidence of fault deformation along a transect following a known steep gradient in the GPS velocity, which has been suggested to indicate creep or shallow fault locking. By generating digital elevation models (DEMs) from Pléiades stereo-satellite imagery and drone photogrammetry, complemented with available High Mountain Asia DEMs, we document distributed east-west trending thrust faulting along a 3-5 mm/yr north-south GPS velocity gradient. In a paleoseismic trench at the eastern end of the transect, less than 10 km north of the Karkara Rangefront Fault (near the Kazakh-Kyrgyz border), faults with at least 0.5-m of displacement overthrust deposits of Holocene age. Westward, in the Issyk Kul basin, sub-parallel young folds that appear to be underlain by shallow thrust faults accommodate shortening. Further southwestward, fresh-looking scarps and vertical offsets no larger than 3 meters along E-W thrust faults in the Karakudzhur and Naryn basins may indicate single-event offsets, with the lateral extent of continuous fault scarps empirically equivalent to the rupture lengths of M ~7 earthquakes. Infrared stimulated luminescence dating in a paleoseismic section in Naryn suggests that slip on the fault, of at least one meter, happened after 4.2 ka. Constraining the aseismic and seismic partitioning with existing data remains elusive; nevertheless, the semblance of scarps with known earthquake ruptures in the region and the present-day shortening inferred from GPS data highlight the importance of studying the potential seismic hazard of faults in the interior basins.

Earthquakes of the Silk Road – an overview of results from the EROICA program

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We present an overview of outputs from the Leverhulme Trust EROICA program (Earthquake ruptures of Iran and Central Asia). The program aims to explore the variability of earthquake rupture styles and fault behaviours within the interior of Asia using a range of techniques, that make use of the extremely well preserved landscape, the abundant and rich cultural heritage, and the often long and detailed historical record. We combine field observations (geomorphology, paleo-rupture mapping, and paleoseismology), optical satellite image and digital elevation model analysis, earthquake seismology and epicentral location using heritage datasets, and combined historical-archeological-geological analysis. Our results have helped us at local scale to understand the sources of individual historical earthquakes, and to better appreciate the vulnerability of specific cities and infrastructure sites. More generally we are slowly building an appreciation of plate interior earthquake rupture styles and variabilities that stretches over an appropriately long time span (>1000 years), and over a sufficiently wide region, that we are able to explore the processes in rare but very large events.

Slip variability and temporal clustering along the Imperial fault at Mesquite Basin, Imperial Valley, California

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Paleoseismic trenches across the Mesquite Basin section of the Imperial fault revealed channels that cross the fault at high angle and that are displaced in the subsurface. These channels incised into and are embedded within lacustrine strata associated with Lake Cahuilla fillings. Three-dimensional excavation of these channels yielded information on slip in the past six surface ruptures. Displacement is well documented for the 1940 and 1979 events, with 15–20 cm of coseismic lateral slip in each event at the site. A small rill is deflected by ~60 cm, which we attribute to the 1940 and 1979 events plus creep and afterslip.

In contrast to the modern deflected channel, two subsurface channels, each ~50 cm wide, are beheaded with no rounding of the channels or flow along the fault. This relationship argues that displacement in each of the corresponding events—the sixth and fifth events back (E6 and E5)—exceeded 50 cm; the channel spacing suggests slip of 1.4–1.5 m in each event. A younger channel complex contains a sequence of nested channels that suggest two additional surface ruptures—the fourth and third events back (E4 and E3)—with smaller displacements than in E6 and E5.

The ages of these past surface ruptures are constrained by local ^{14}C dating, by the stratigraphic relationship of each event horizon to lacustrine intervals, and by the regional late Holocene lake history. The youngest pre-1940 event (E3) occurred when the site was underwater, around the time of the most recent Lake Cahuilla highstand, ca. 1732 CE. Events E4–E6 all occurred between then and ca. 1520 CE. The oldest channel, beheaded by E6, is offset a total of ~5.0 m. Hence, the northern Imperial fault has sustained ~5.0 m of slip in the past ~500 years, with the majority (~4.4 m) occurring in the four earlier events between ~1520 and ~1732 CE. These results imply that slip per event at the site ranges from ~0.15 to ~1.5 m, and the slip rate for the Imperial fault in the Mesquite Basin averages ~1 cm/yr for the past five centuries but varies over time.

Rupture History of the Himalayan Frontal Thrust in east and in west of Bagmati River, Central Nepal

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The 2015 Golkha earthquake raised concern about the future large earthquake in south of the 2015 source area. The Golkha earthquake ruptured 10 to 20 km deep portion of the plate boundary interface ~50 km away from the surface trace of the Himalayan Frontal Thrust (HFT). Therefore it is necessary to evaluate the earthquake potential of the shallowest part of the thrust in central Nepal. After 2018 and 2019 paleoseismology works in Butwal area, in 2020 we excavated two trenches on the Himalayan front in east and in west of Bagmati river to examine the terminations of past events and to know the rupture history. At the Dumachaur Khola site 4 km east of Bagmati river, 3 or 4 events in 3500 years are excavated. The penultimate event here is dated around 3000 year B.P.. At the Gopalkoti-Dandatol site, 0.7 km west of Bagmati river, 3 events between 7th and 14th century C.E. are recognized. 1934 ruptures do not appear and 1255 (or 12th century) event is the last event in both trenches. The exposures were excellent with the master thrust fault through layered fine sedements containing many charcoal pieces, but the interpretation of the even time-series is difficult. Findings from three trenches around Butwal and these two across Bamati River are as follows. (1) 1934 rupture did not reach Bagmati River in west. (2) In west of Butwal, the timing of the last surface rupture coincides with 1344 earthquake without any evidence of 1255 (or 13 century) and 1505 ruptures around Butwal. (3) The last event around Bagmati River crossing occured in 1255 or in 12th centrury. (4) The timing of the penultimate event in west of Bagmati River is about 1000 year B.P. while it is about 3000 year B.P. in east of Bagmati River. Though a lot of paleoseismological works has been carried out along the HFT in central Nepal and Central Seismic Gap, we still know little about penultimates event on most segments.

Session 125: African Quaternary Anthro-environments: Palaeoecology and cultural responses to environmental variance

Hominins and Environmental Change: A Tale of Two Taxa

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It is generally understood that gauging the impact of climate/environmental change on hominin speciation, extinction, and distribution requires well-resolved paleoenvironmental data. To date, however, there has been less focus on how hominin ecological diversity and competitive mammalian interactions modify hominin interactions with the environment. In this paper, I discuss this lacuna through the lens of two hominin genera that are believed to be ecologically disparate: *Paranthropus* and *Homo*. I argue that even though these taxa are in many ways well understood, arguments about the impacts of climate/environmental change for each are seriously underdetermined. One of several reasons for this is our lack of knowledge about how these Pleistocene primates, and their chief competitors, used resources within their habitats.

The norm not the exception: MSA open air sites in the Kalahari reflect early human behaviour and adaptation to dryness

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An assumption of early human absence, avoidance or departure has influenced the reading of interior southern African dryland anthro-landscapes for many decades. Whether by design or accident, this has shaped theories of evolution, adaption and dispersal during the Middle Stone Age. The vast interior dryland of southern Africa (the Kalahari, from the Orange River north to the Okavango) has not figured large in direct investigations of MSA adaptations and has widely been assumed to have been relatively empty or avoided due to dryness post- 130 k yr. Interest in the region's archaeology has recently re-emerged, with intensive investigations of key sites on the southern margin (Wilkins, 2020) renewing interest in the subcontinent's interior as a place of early human innovation and adaptation.

New assessments show that the heart of the Kalahari too is replete in unexplored open air sites (Coulson et al., 2022), that when intensively investigated reveal an outstanding richness of records of early human response and adaptation to environmental change and dryness (Thomas et al., 2022). We show how interdisciplinary investigations can reveal a detailed picture of direct, positive and not isolated responses by MSA human to environmental conditions more generally regarded as challenging and inhospitable.

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Wilkins, J. 2020. Homo sapiens origins and evolution in the Kalahari Basin, southern Africa. Evolutionary Anthropology. doi 10.1002/evan.21914.

New insights into the late Pleistocene paleoecology using δ13C and δ18O enamel isotope evidence from Gotera, Southern Ethiopia

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The origin of behavioral modernity, geographic dispersal, and technological development of Anatomically Modern Humans (AMH) coincided with the profound late Pleistocene stadial, and interstadial climatic episodes might have impacted human adaptation and resilience. It has been argued that tropical eastern African highlands with locally available resources such as water, landscape setting, precipitation, and highland forests were potential refugia during the Late Pleistocene environmental and climatic stresses. Nonetheless, this aspect becomes obscure in Ethiopia where site-specific environmental and climatic records of MSA sites remain poorly studied. Here, we present the result of $\delta^{13}C_{enamel}$ and $\delta^{18}O_{enamel}$ stable isotopic analysis of bulk and sequential samples (n=62) of mammalian teeth enamel from Gotera. The newly discovered MSA site of Gotera in southern Ethiopia dated to the Marine Isotope Stage 3 (MIS 3) provides fresh data about the ecological context of AMH. We discuss the new insights into the environmental and climatic contexts as well as the subsistence strategies of AMH in southern Ethiopia.

Assessing past human-vegetation relationships in the SW Ethiopian highlands using wood charcoal identification

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The highlands of South West Ethiopia are part of the Eastern Afromontane biodiversity hotspot. They host more than 5200 vascular plant species of which about 10% are endemic. Nowadays, the vegetation of the highlands is highly impacted by human pressure and in particular agropastoralist activities which have led to a dramatic deforestation. The remaining patches of Afromontane forests grow between 1800 and 3000 m asl, where the rainfall and temperature ranges are suitable to allow their persistence. As the highlands capture higher rainfall than the lowlands, it has been hypothesized that they may have acted as refugium areas during dry periods, for example after the African Humid Period, while the lowlands were undergoing aridification and resource depletion.

So far, no palaeoecological data are available in the SW highlands to test this hypothesis. Yet, archaeological excavations led in rock shelters in the last decade have provided abundant and well-preserved palaeobotanical remains, including macroscopic wood charcoals and phytoliths dating back to the end of the African Humid Period.

Here, we present the results of the wood charcoal analysis from the Sodicho and Mochena Borago rock shelters, located in the SW highlands at 1900 and 2200 m asl, respectively. Charcoal assemblages from Sodicho indicate an opening of the dry Afromontane forest linked to human activities (fires) after the African Humid Period. This is evidenced, for example, by the dominance of a fire-tolerant Proteaceae and *Acacia* sp. in the assemblage as well as burnt phytoliths. Charcoal analysis from Mochena Borago is still ongoing, but so far, the forest around this rock shelter seems to have been less impacted, as indicated by the presence of typical forest taxa (*eg.* the gymnosperm *Podocarpus falcatus*). Our results suggest that even if the highlands may have kept a forest cover during dry periods, human activities were also shaping the landscape in some areas, showing that people were not necessarily seeking refuge in dense forest cover but were also actively modifying it, likely to improve resource availability.

Benthic foraminifera from the nearshore area of the Mediterranean coast of Central and NW Libya: A preliminary survey

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The Mediterranean Sea is among the hotspot's areas severely affected by biological invasion, particularly benthic foraminifera. This survey is an attempt to record and identify the benthic foraminifera in the Mediterranean coastal area of Libya. A total of seven samples were collected along 500 km of the Libyan coastal area, from Sabratah in the NW to Sirte in the central, for studying the sediments physical characteristics and foraminiferal assemblages' composition. Sediment textures were mainly fine to very coarse sand dominated by calcareous bioclastic debris of mollusks, echinoids, and foraminifers, with minor quantities of ostracods and bryozoans. The total number of species recorded in all samples is (25) species were identified, and one Indo-Pacific species, "*Amphistegina lobifera*," was recorded. The average value of the population density (number of specimens individuals per gram of dry sediment) was low to moderate, averaging about 154, with the lowest count at Tajurah Coast. The foraminiferal assemblages of the northwestern area, extending from Sabratah to Misratah, were low-diversified and abundant (D) only with *Amphistegina lobifera* and *Textularia agglutinans*. The central coastal area extended from Bu'ayrat al Hasun to Sirte has a high species diversity (S) and is dominated mostly by milliolids. *Amphistegina lobifera* is currently rapidly broadening its biogeographic range in the Mediterranean Sea with increasing temperatures brought on by climatic change, especially in the oligotrophic waters dominating the Libyan coastal area. However, this study recommends that a detailed investigation be accomplished to study the invasive species in the Libyan coastal area and the associated environmental consequences.

Paleoclimate models and vertebrate archaeofaunal assemblages in Pleistocene Africa

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This research presents vertebrate faunal taxonomic identifications from two Late Pleistocene archaeological sites in Africa: 1) Contrebandiers Cave, Morocco, and 2) Iho Eleru, Nigeria. Contrebandiers Cave is located on the Atlantic coast of Morocco and contains Middle Stone Age and Later Stone Age deposits with 11,000+ point-provenienced vertebrate faunal remains. Iho Eleru is a rock shelter in southwest Nigeria with approximately 200 vertebrate faunal remains. Both archaeological sites have been chronometrically dated and the ages have been published elsewhere. The habitat preferences of the identified taxa from both sites were used to reconstruct the past habitats surrounding each archaeological site. Paleoclimate from global circulation models was used to reconstruct the past climates surrounding each archaeological site. Climate data was accessed using pastclim (an R package for paleoclimatic reconstructions), and archaeofaunal data was collected by the primary author and has been published elsewhere. For both archaeological sites, the modelled paleoclimate matches the habitat reconstructions based solely on archaeofaunal remains. This suggests that paleoclimate from global circulation models–such as those used in pastclim–and Late Pleistocene African animal distributions agree with each other.

Session 126: Sub-annual to decadal records of environmental change

High-resolution reconstructions of Holocene ENSO from the Great Barrier Reef using short-lived marine gastropod shells

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In recent years, there has been a growing interest in using short-lived marine mollusc shells as a paleoclimate archive by virtue of their ability to preserve high-resolution paleoclimatic and paleoenvironmental information in multiple biogeochemical proxies. Moreover, valuable information about past environments, human-environmental interactions, and seasonal foraging practices can be obtained via the analysis of marine gastropods from archaeological sites. *Rochia nilotica* and *Conomurex luhuanus* are two of the most common archaeological shells excavated from shell middens spanning the Mid-to-Late Holocene, in the northern Great Barrier Reef (GBR); however, their use as archives to reconstruct the Mid-to-Late Holocene ENSO (El Niño-Southern Oscillation) has not yet been tested. In this study, we compare temporally successive oxygen isotope and trace element records (d18O, Mg/Ca, Sr/Ca, and Ba/Ca) in modern *R. nilotica* and *C. luhuanus* shells with instrumental environmental records to test whether we can quantitively reconstruct past environmental parameters. Preliminary results show that modern *R. nilotica* and *C. luhuanus* reliably record environmental factors (e.g. sea surface temperature and salinity) in equilibrium with the surrounding environment at monthly to daily resolutions. These proxies will ultimately be applied to reconstruct localised Mid-to-Late Holocene ENSO records at sub-seasonal scales in the Great Barrier Reef. Results obtained from this ongoing research can be used to compare with climate model simulations to provide more robust reconstruction of paleo ENSO behaviour and offers an opportunity to decipher the long-term shellfish management strategies of Indigenous peoples in the GBR environment to provide a baseline for future marine resource management in the GBR.

Toward a novel multi-century archive of tree mast using pollen from varved lake sediments

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Mast seeding – the pronounced inter-annual variability and synchrony in seed production – can have profound local ecological impacts. In New Zealand forests, mast years lead to rapid increases of non-native mouse populations, followed by increases in non-native mustelids, which in turn predate highly vulnerable native bird and reptile fauna.

We explore the potential for generating long (centuries to millennia) proxy records of tree mast seeding, from pollen deposited in lake sediments. This proxy record uses pollen recovered from varved sediments from a core collected from Lake Ohau, South Island, New Zealand to reconstruct masting events for two genera of Southern Beech, *Fuscospora* spp. and *Lophozonia* spp. We find average mast frequencies inferred from *Fuscospora* pollen from a 43-year sediment core collected from Lake Ohau comparable to seed fall expected for the catchment using a differential-temperature (ΔT) statistical model for the period 1974–2016. In contrast, *Lophozonia* pollen mast frequency in the 1974–2016 timeseries was consistently lower than that predicted by the ΔT model, although the patterns of variability were broadly similar.

We explore this approach in a second 32-year pollen timeseries from Lake Ohau, spanning the pre-instrumental period 1833–1864. During this interval, average air temperature was ~1°C cooler than the late 20th century, and interannual variability of air temperature was subdued, such that mast frequency predicted by the ΔT model is the lowest in 200 years. We find mast frequency in our pollen records reflects this pattern for *Fuscospora*, with a minima of mast frequency from 1850, compared to the 1974–2016 record, but not for *Lophozonia*.

This paper demonstrates that a centuries-long pollen record from the varved Lake Ohau sedimentary sequence has the potential to form a valuable proxy for *Fuscospora* masting that would supplement existing seedfall records. Long records of this type could significantly enhance our understanding of the environmental drivers of mast seeding.

From source to sink: paleoenvironmental reconstruction along the MIS 3 Rhine River with mammoth teeth

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Mammoth teeth are increasingly studied with stable isotopes for paleoenvironmental reconstructions during the past decades due to their frequent discoveries and capacity of recording sub-annual scale paleoclimatic variations. In this study, eleven molar teeth of woolly mammoth (*Mammuthus primigenius*) coming from different locations within or near the Rhine River catchment were studied for oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotopic compositions in their enamel carbonate. The samples were radiocarbon dated to several time windows during approximately 33-40 ka cal BP, and they were discovered in the fluvial sediments of multiple locations in Swiss Alps and Upper Rhine Graben, as well as dredged from the southern North Sea, covering from the approximate origin to the downstream delta of the Rhine Catchment during Marine Isotope Stage 3 (MIS 3).

We sequentially drilled the enamel of all specimens following the growth direction at millimetre resolution, and the obtained enamel powder was analyzed for $\delta^{18}O$ and $\delta^{13}C$ values using IRMS mass spectrometry. We then plotted time-series of $\delta^{18}O$ and $\delta^{13}C$ variations from all sample locations, and the high-resolution records were interpreted to reconstruct a variety of paleoenvironmental properties, including river hydrology, precipitation, air temperature, vegetation composition and sub-seasonal scale climatic changes. These paleoenvironmental properties were compared between different sample locations to investigate the spatial gradients in paleoclimatic and paleoecological conditions, as well as river hydrological balance, from south to north along the Rhine River. These high-resolution isotopic data were further combined with regional sediment and pollen records to provide a high-resolution framework for reconstructing the complex and variable paleoenvironmental conditions of MIS 3 in Central Europe.

A proxy calibration study for a freshwater archive in south-east Australia and its implications for understanding past human-animal-environment relationships

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Sub-annual proxy archives are lacking from the Central Murray River Basin (CMRB) in south-east Australia, which lies on Ngintait and First People of the Millewa Mallee Country. As people have been living in this region for at least 15,000 years, the development of sub-annual paleoenvironmental proxy archives could provide valuable insights into human-environment interactions during the diverse climatic and environmental changes of the Last Glacial Maximum – Holocene transition. The large number of shell midden sites found along the Murray River provide the potential for archaeological freshwater bivalve specimens to act as sub-annual, local archives, with the approach known as sclerochronology, unlocking details of the relationship between shell growth patterns, associated geochemistry, and the ambient environment. However, before archaeological material can be interpreted, a modern calibration study must be completed to understand the robustness and reliability of the proxy archive.

This paper presents the results of a modern calibration study of the freshwater bivalve species *Alathyria jacksoni*, collected live from the CMRB in 2017 and 2021-2023. The study also included the collection and analysis of water samples, and water and climate data. The mollusc specimens were analysed using various techniques, including SEM, SIMS (SHRIMP), IRMS and LA-ICP-MS, to understand how the growth and geochemistry of modern *A. jacksoni* shell specimens relates to the surrounding environment and hydrochemistry of the current Murray-Darling Basin system. Apart from the relevance of this analysis for archaeological and paleoenvironmental research, this investigation also provides valuable insight into the life history and behaviour of the *A. jacksoni* population, which may aid current efforts to better understand and conserve this freshwater mollusc species. Given the species range of *A. jacksoni*, the results of this study are applicable to paleoclimate research throughout the Murray-Darling Basin.

Marine shell isotope records of Holocene temperature and upwelling shifts on the west coast, South Africa

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The arid west coast of South Africa features substantial Holocene and late Pleistocene archaeological deposits of shellfish remains in both open-air coastal middens and rockshelters. These deposits, testament to millennia of coastal forager subsistence behaviours, also preserve rare regional archives of seasonal climate information in the shell geochemistry. We present a modern study of serial stable carbon and oxygen measurements for the limpet Cymbula granatina, from locations upstream and downstream of a large, summer upwelling cell, demonstrating the utility of this species for palaeoclimate and seasonality studies. We reconstruct shifts in sea surface temperatures and upwelling activity from the well-dated archaeological sequence at Elands Bay Cave and nearby sites. We also examine marked shifts in the annual scheduling of hunter-gatherer shellfishing in the region across the period. We discuss these patterns with respect to the broader archaeological record, particularly changes in settlement patterning and the arrival of pastoralists to the region.

Demonstrating the relationship of Araucariaceae tree-ring width and Carbon-13 measurements to climate in subtropical Eastern Australia

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In the past decade, high-resolution tree-ring records from the tropics and subtropics of Australia have been developed, enabling climate reconstructions in a region that generally lacks both historical and instrumental climate data. Most tree-ring work in tropical and subtropical Australia focuses on ring-width measurements, while tree-ring stable isotope studies are relatively few. Stable isotopes in tree rings often provide complimentary climate information to tree-ring width analysis relating to different environmental variables. Rigorous studies of tree-ring stable isotopes have not been widely undertaken in the Australian tropics. Here we present a comparison study between ring-width measurements and isotopic data for a subtropical Australian site in Lamington National park, Southeast Queensland. Annual tree-ring chronologies from *Araucaria cunninghamii* trees have been developed spanning 1805-2014 CE using ring-width measurements from 18 trees, and for 1950-2013 CE based on Carbon-13 from 5 trees. The dating of these chronologies was confirmed using radiocarbon measurements and densitometry. Climate correlations demonstrate that while both chronologies capture moisture variability, their signals are not identical. Preliminary analysis suggests the isotopic signal provides a regional representation of conditions that the more localized ring-width signal. Extending on this analysis, the ring-width chronology was used to develop a drought reconstruction which clearly indicates a recent step shift in drought conditions in Southeast Queensland, potentially demonstrating an anthropogenic influence on this region's climate. This study illustrates the importance of investigating multiple forms of environmental evidence when undertaking dendrochronological studies in the tropics and subtropics where we are limited to relatively short historical climate records.

Palaeoenvironmental context for Middle to Upper Palaeolithic hominins in the Levant from multi-proxy analyses of marine and terrestrial gastropod shells

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The Levant was a key corridor for dispersals and interactions between hominin species during Marine isotope stage 3 (MIS 3). This project investigates whether seasonal environmental changes associated with rapid climate events played a role in the expansion of our own species, *Homo sapiens* (modern humans), and the demise of Neanderthals during this time in the Levant. Humans respond to changes in their local environment on daily to seasonal timescales. Therefore, robust assessments of the impact of environmental change on human behaviour requires an understanding of local environmental change at seasonal to sub-seasonal resolution. Applying sclerochronology (the analysis of incremental growth structures) and geochemistry to mollusc shells can provide some of the few sub-seasonal resolution palaeoenvironmental proxies in the mid to high latitudes. Obtaining these records from food-refuse archaeological specimens enables the reconstruction of paired records of how humans responded to environmental changes in the past.

Here we present high-resolution environmental reconstructions from stable isotope analyses of marine gastropods (*Phorcus turbinatus, Patella caerulea*), and land snails (*Helix spp.*) from several key Middle to Upper Palaeolithic archaeological assemblages in the Levant. Serially sampled δ^{18}O, Mg/Ca, and Sr/Ca analyses of marine gastropod shells provide sub-monthly snapshots of sea surface temperature, whilst δ^{18}Oand δ^{13}C analyses of terrestrial gastropod shells provide sub-seasonally-resolved records of rainfall variability and vegetation change. This evidence for fluctuating temperature, rainfall and seasonality regimes throughout MIS 3 appears to be linked with northern hemisphere millennial-scale climate oscillations These highly resolved environmental records, coupled with well-dated archaeological sequences provide a framework for assessing the complex interplay between early modern humans, Neanderthals and their local environments. The archaeological records show *Homo sapiens* occupation occurred during both warmer and cooler phases and during both high and low seasonality regimes, indicating that modern human populations showed resilience in the face of environmental fluctuations and resource uncertainty. We are examining whether this changing seasonality played a role in the demise of Neanderthal populations in the region. These paired cultural-environmental records demonstrate the importance of generating local, high-resolution palaeoenvironmental records to enable nuanced examinations of human-environment interactions during critical periods of the late Pleistocene.

1000-years of reconstructed summertime extreme jet stream behavior driven by a wavenumber-5 Rossby wave pattern

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In the Northern Hemisphere, the jet stream is an important driver of terrestrial climate, including extreme events such as heat waves. As such, there is interest in understanding the jet stream's response to anthropogenic greenhouse gas forcing. One hypothesis posits that under anthropogenic global warming, the jet stream is becoming more meandering, or wavier, which can be described by the "wavenumbers" of planetary Rossby waves that influence jet stream position. Wavenumbers have been described in studies focused on the instrumental period, which demonstrate that some summertime wavenumber patterns, such as wavenumbers 5 and 7, are associated with a meandering jet stream that drives hot, dry conditions in regions of North America, Europe, and Asia, impacting important food production regions. Despite interest in current and future jet stream behavior, little is known about its past and natural variability, making it difficult to determine whether these wavenumbers have become more frequent in recent decades.

In this first attempt to reconstruct Northern Hemisphere Rossby waves and associated jet stream behavior using paleoclimate data, we present a 1000-year reconstruction of summer extreme wavenumber 5 (wave-5) events based on tree-ring-inferred Palmer Drought Severity Index (PDSI) data compiled in the North American Drought Atlas (NADA) and the Old World Drought Atlas (OWDA). We developed a wave-5 index as our reconstruction target based on the number of weeks during May, June, and July that wave-5 is in its preferred Rossby wave phase to induce simultaneous droughts. Our reconstruction targets PDSI anomalies associated with extreme wave-5 events in three regions across the Northern Hemisphere (two in NADA and one in OWDA) using a stepwise linear regression, and explains ~40% of wave-5 variability over the instrumental period (1948-2005). Our results suggest that the recent occurrence of extreme wave-5 jet stream positions is not increasing, and that this aspect of jet stream behavior has remained stable under global warming. We also show that these wave-5 positions are related to the El Niño Southern Oscillation, where wave-5 is more likely to be in these extreme phase positions during La Niña events, consistent with analyses focused on the instrumental period.

Interface of tree-ring δ18O spectrum across moisture regime of southeastern Tibetan Plateau

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The present study area encompasses the "Third Pole of the earth" which is considered as "Water tower of Asia" strongly influencing the hydroclimate for a large population in East and South Asia. The varied topography of the region results in its complex hydrological regimes, resulting in its high sensitivity to climate change. The inadequate long-term climate observation is however, not sufficient to understand the climate dynamics and to model and predict the climate scenario. The strengthening of long-term quantification of hydrological changes under changing climate is significant for water managers and policy-makers to develop sustainable water resources strategies. With view to this, we reconstructed gridded summer (June-August) precipitation totals for southeastern Tibetan Plateau encompassing eastern Himalaya region using network of tree-ring $\delta^{18}O$ records. This precipitation reconstruction characterized the hydroclimatic variability in terms of drought and pluvial since 489 CE. The reconstruction was assessed for its variability and strengths with special emphasis for major global climatic events i.e., medieval climate anomaly (MCA) and little ice age (LIA). The declining trends of moisture variability during mid 19th century to recent is observed which might be the serious concern for future sustainable hydroclimatic scenario of the region. The gridded precipitation reconstruction shows affinity with sea surface temperature (SST) of the Indian and Pacific Oceans.

Session 127: Uncovering the environmental legacies of colonialism

Palaeoecological insights on ecosystem management in Cape Pillar, lutruwita/Tasmania, to promote biocultural heritage and enhance tourist experience

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Cape Pillar is part of the Tasman National Park in lutruwita/Tasmania, SE Australia, and home to some of Australia's endemic species, as well as a major tourist destination in the Southern Hemisphere. However, projected frequent drought and fire weather in SE Australia over coming decades has triggered growing concerns about the future of the dense sclerophyllous vegetation that currently dominate the Cape. Given that the Cape has been occupied by the Palawa Indigenous people of lutruwita for millennia before their removal by European colonists, understanding the nature of vegetation and fire regimes before and after European invasion will provide a solid knowledge base for management actions in the Cape Pillar area. Using a multi-proxy palaeoecological method combined with historical aerial photography and oral accounts of early Europeans voyages to Cape Pillar, we show that major bushfires only became common in the Cape after the removal of Palawa people in the early 1800s. Open diverse vegetation with low fire activity was maintained by Palawa people in the Cape for over two millennia and was subsequently replaced by dense scrubby vegetation after colonisation, with major bushfires at least every 3–4 decades, exacerbated by climate change over the last century. Long-term management programmes targeted at restoring pre-colonial open heathland will not only promote biocultural heritage in Cape Pillar but will also protect tourists and the multi-million dollar infrastructure in the region.

Land-use change in Hispaniola before and after Columbus' arrival

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We reconstructed human impact and environmental change from 2 sediment cores in the Cibao Valley. We studied 2 cores from sediment-filled meanders of the Yaque River and 1 core from the coastal mangrove forest. From 195 CE meander infill is documented by changing grain size distributions, organic matter concentration, and pollen from wetland plants. Indigenous populations must have increased since 1050 CE. Between 1250 and 1450 CE pre-colonial modifications of the landscape were primarily the result of fire-use and small-scale clearings for crop cultivation and slash-and-burn agricultural practice. After Columbus' arrival in Hispaniola (1492 CE) European diseases caused indigenous sites became abandoned. Increasing coprophilous fungal spores evidence Europeans had introduced cattle rapidly leading to more open forest. Intensive land-clearing and large-scale agriculture on the moist and nutrient rich soils along the Yaque River expanded from 1650 CE onwards. Colonists and introduced enslaved labour force increased causing deforestation and erosion. Two centuries after European colonizatio(18thC) land-use in the Cibao Valley had become a balance between substantial livestock and crop cultivation. Pollen grains have evidenced cereals, maize, and potentially also sugar cane, amaranthaceous crops and tobacco. After 1950 CE, swamp vegetation of *Typha* and Cyperaceae decreased, pointing to an almost fully terrestrialized meander with little standing water, reflecting the present-day setting. This multiproxy reconstruction of anthropogenic environmental change shows a clear differentiation between an immediate introduction of livestock and after some 150 years the development of a European style agriculture, providing a context for archaeological investigations. Mangroves near the first permanent European colonial outpost in the Americas underwent no significant impacts. During the last 200 years all natural ecosystems suffered from severe deforestation, degradationand implementing an irrigation system leading to the present cultural landscape.

Pre-European Ecology on the Northern Plains

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The Great Plains grassland has been called the "American Serengeti." Before their near-demise or extinction, in the 19th Century, bison (*Bison bison*), pronghorn (*Antilocapra americana*), deer (*Odocoileus* spp.), elk (*Cervus canadensis*), and their predators, grizzly bears (*Ursus arctos horribilis*), and wolves (*Canis lupus nubilus*), the grassland year must have resembled the so-called "grazing succession" of East Africa. In this sequence, smaller herbivores, then larger ones, take advantage of available forage in a predictable sequence as the season progresses. Notably, grass protein is highest in spring but declines later in the year. A major difference between the African and American grazing year is Africa's lean time is the dry season while northern plains animals must contend with winter's cold and snow. With climate as the driver, I hope to unravel the various animal ecologies during the late 18th Century.

Adding fuel to the fire: have fires in Southeast Australia always burned so hot?

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Prior to colonisation by Europeans, many landscapes around the world had been deliberately shaped, maintained and cared for by Indigenous peoples using skilful land-management practices. These land management practices were suppressed and eradicated via colonisation; subsequently replaced with the imposition of European landscape ideals. This shift in management has led to a broad set of environmental consequences that pose contemporary challenges, many of which are now being compounded by the impacts of climate change. Recent catastrophic wildfires have kindled discussion about the return and expansion of Indigenous cultural burning practices to mitigate against climate-driven catastrophic wildfires across these landscapes.

Causes for catastrophic wildfires across Southeast Australia are framed around four themes: 1. Climate change; 2. Ignitions; 3. Fuels; and 4. Risk-adverse policy frameworks. Compounded with these are wilderness ideologies, which have allowed for policy and research to ignore past ecological conditions and ignore and suppress a wealth of Indigenous knowledge of healthy landscape management. Here, a synthesis of our palaeoecological research from across Southeast Australia is discussed to highlight coherent trends of landscape change pre- and post-British Invasion. By doing so, we aim to understand the influence of Aboriginal management, namely fire, and the consequences of the removal of strategic and managed burning across Southeast Australia. Through this research, we can develop datasets of environmental change spanning the pre- to post-British Invasion period to create appropriate baselines and management approaches that can guide future landscape management of the Southeast Australian landscape.

Ngā wā taio Māori o mua: Past cultural ecosystems in Aotearoa

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The prevailing depictions of the environmental past of Aotearoa New Zealand are heavily focused on 'pristine pre-human' ecosystems. These come at the expense of our understanding of the dynamic cultural ecosystems that Māori constructed prior to European colonisation. Furthermore, Māori continued to dominate the economy of Aotearoa well-into the colonial period up until the 1870s, producing most of the food supply. Yet, our understanding of how Māori adapted their cultural landscapes to the colonial economy is limited and poorly explored using palaeoecological tools. Indeed, most restoration, conservation and Quaternary scientists in Aotearoa appear to remain intent on bypassing the pre- or post-colonial past.

Vast kūmara (*Ipomoea batatas*, sweet potato) cultivations, for example, once connected hundreds of pā (fortified villages) and kainga (villages) across the extensive flood plains of Waikato Awa (Waikato River) revealed by archaeological excavations. These cultural landscapes are monumental, but continue to be destroyed with ongoing land development. Kūmara cultivations formed on mounds (puke) and borrow pits (rua) have been well described, but little is known of the cultural wetland ecosystems that buffered the margins of forests, lakes and rivers, that are now target areas for continued drainage, or ecological restoration for emission trading schemes. Here, insights into pre- and post-colonial cultural ecosystems are drawn from fossil records from wetlands, capturing the last 1000 years of ecological change. Early 14th century archaeological and palaeoecological evidence for irrigated taro (*Colocasia esculenta*) cultivations are presented, reflecting the ancestral cultural ecosystems of the tropical Pacific Islands. Evidence for later adaptation and expansion of kūmara cultivation in the 16th century, as well as the production of potatoes (*Solanum tuberosum*) for the growing colonial market in the early 19th century, is explored. Together with Mātauranga Māori (traditional Māori knowledge), the palaeoecological data captured from lake and swamp sediments could provide baseline ecological data for cultural restoration projects, further reawakening indigenous pride in the achievements of Ngā Tīpuna (the ancestors).

What was the impact of British invasion on vegetation and fire-regime in southeast Australia?

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Extensive areas of Victoria, a relatively fertile region of southeast Australia, are the homelands of a number of Aboriginal groups who have managed them for millennia using construction, aquiculture and burning methods. Post British invasion, the value of this region was rapidly recognized for Europeans and the land was quickly stolen by settlers for agriculture and livestock. To what extent this shift from an Aboriginal management of country to European-style land management affected the landscape remains an open question. Here we present detailed fossil pollen and charcoal records from sediment cores obtained from Lagoon Landsdale located in Victoria, southeast Australia, to examine vegetation and fire-regime changes since the British invasion. Our data shows a considerable change in vegetation composition and fire activity following invasion and dispossession of lands, and provides a quantitative benchmark for future management of this area and further afield.

A Tale of Two Lakes: Cultural Landscapes, climate change and the environmental legacies of colonialism on the tropical islands of New Guinea and Timor-Leste.

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The tropical rainforests of New Guinea and Timor-Leste have been inhabited by culturally and linguistically diverse peoples for more than 40,000 years, creating cultural landscapes that have endured and adapted through extremes of climatic and social change. The cultural landscapes of New Guinea and Timor-Leste have come under increasing pressure from mining, population growth, land clearing, invasive species, and novel pollutants within the last 300 years of colonial expansion and exploitation. This study details the last 4000 years of environmental change in two large lakes – Ira Lalaro (Timor-Leste) and Lake Kutubu (Papua New Guinea) – and demonstrates through multi-proxy palaeoenvironmental indicators the unprecedented transformations in aquatic and terrestrial biota that have occurred in the last 300 years of colonialism. We argue that the incorporation of an adequate historical perspective into models for wetland management and conservation combined with traditional ecological knowledge is critical to mitigate the impacts of ecological catastrophes such as biodiversity loss into the future.

Session 128: African Acheuleans in the Early/early Middle Pleistocene: triggers, techno-subsistences, time-lines

From East to North-West: magnetochronological contribution in dating the oldest African Acheulean archeological sites

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Magnetostratigraphy is a key tool for the temporal interpretation of archeological stratigraphies of Quaternary age. Magnetostratigraphy provides age constraints of archeological levels as well as correlations between distant series using chronostratigraphic (time-equivalent) surfaces represented by magnetic polarity reversals, offering the opportunity to place in a common temporal framework critical archeological site for a better understanding of human evolution.

We present the magnetostratigraphic results from the Melka Kunture (Upper Awash Valley, Ethiopia) and Thomas Quarry I (Casablanca, Morocco) archeological areas providing a new temporal framework for human presence and for the first local occurrence of the Acheulean lithic technology in two sites located at the opposite edges of the African continent during the Pleistocene. Each site is associated whit a peculiar litostratigraphic context since at Melka Kunture the archeological levels are enclose within a volcano sedimentary succession characterized by reworked volcaniclastic material variably intercalated with cinerites and tuffs in primary position, some of which have been dated with radiometric techniques, while at Casablanca the sedimentary formation hosting the archeological layers is characterized by coarse-grained biocalcarenites, calcirudites and cave continental infill deposits.

Our data combined with numerical age data from the literature, allowed to reconstruct age models of sedimentation and thus the ages of the archeological levels therein contained.

According to our age-depth depositional models, main archeological levels at Melka Kunture resulted ranging from ~0.6 Ma to ~2.1 Ma, with the notable first emergence of Acheulean technology in Ethiopia estimated at 1.95 (-0.025; +0.1) Ma. At Casablanca, our data indicate the occurrence of early Acheulean technology at ~1.3 Ma**.**

What zooarchaeological evidence for animal consumption during the emergence and development of the Acheulean in Africa?

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The discovery of cut-marked bones (3.39 Ma, Dikika, Ethiopia) and lithic artefacts (3.3 Ma, Lomekwi 3, Kenya) prior to 3 M years in Eastern Africa challenged current views of human evolution by extending the antiquity of animal consumption using stone tools. However, evidence of meat consumption through the identification of butchery marks before 2.6 Ma is still under debate. The current paradigm postulates that diversification of dietary behaviours, with an increasing part of large game hunting and primary access to carcasses, took place shortly after 2 Ma in Africa. From this date onwards the direct evidence of meat consumption becomes more numerous, as well as the first persistent and structured dwellings. At the same time, between 1.9 and 1.7 Ma, we observe the onset of the Acheulean and the emergence of *Homo erectus sensu lato* populations. However, all these changes cannot be causally related, and rather than the result of behavioural evolution, they could be primarily the result of sampling bias. Moreover, most of the cut-marked remains account for only 1% of the faunal assemblages, and some cut mark identification remains questionable or still needs more evidence. Our knowledge probably also suffers from a lack in the development of taphonomic methodology, and contextual and/or historiological biases. Anyway, although meat consumption occurred quite early in human evolution, common meat consumption, complex forms of cooperative hunting, entire butchery sequences and stone and carcass transport, seem to have developed later, after 1 Ma, throughout the African continent and the Levant in conjunction with early Middle Pleistocene environmental and technical changes. Here, we undertake a literature review in order to provide an exhaustive list of faunal collections bearing tangible cut-marked bones from African sites dated to the period of the emergence and development of the Acheulean, between 1.8 and 0.5 Ma.

The earliest appearance of the Kombewa technique within the Acheulian techno-complex: A technological leap or continuous change?

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The Kombewa technique is often regarded as representing a high degree of sophistication in Large Cutting Tool (LCT) blank predetermination strategies in the Early Stone Age Africa. This technique results in a blank with thinner and biconvex faces that requires relatively minor investment at the shaping stage of LCT production. Thus, the technique is innovative in terms of management of the volumetric configuration of LCTs at *debitage* stage. Despite its techno-morphological advantages, use of the Kombewa technique does not appear to have increased throughout the time span of the African Acheulian, for reasons that have yet to be explored.

To date, the earliest appearance of Kombewa technique is reported from the early Acheulian site-complex of Konso at localities KGA7-A2 and KGA8-A1, both dated to between 1.4 to 1.3 Ma. LCTs made on Kombewa flake blanks were also identified in the younger Konso locality KGA12-A1 (ca. 1.2 Ma). The use of Kombewa production has also been recorded in numerous other Acheulian sites across the wider geographic range stretching from eastern Africa to the Levant and Arabian Peninsula, all of them younger than the earliest Konso record.

Recently, utilization of the Kombewa technique has been recorded at locality MW5 (dated to 1.37 – 1.34 Ma) of the Melka Wakena early Acheulian site-complex, on the southeastern Ethiopian highlands, broadly coeval with the earliest record at the Konso site-complex. The two sites are situated within different paleogeographic, paleoecological, and paleoenvironmental contexts and are over 300 kms apart from one another. The co-occurrence of the Kombewa technique at both sites lends itself to explanation as a case of convergent evolution or as a proxy for pace of technological transfer across the eastern African landscape over a narrow temporal span. The current paper discusses the trends in the use of Kombewa technique and its implications for our understanding of trajectories of technological transfer as well as potential models of Homo *erectus* mobility patterns across the diverse landscape of eastern Africa.

Kanyimangin: a new 1 million years old site in West-Turkana, Kenya

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The Early to Middle Pleistocene Transition (EMPT 1250-750 ka) is a period characterised by major environmental changes. These changes are reflected in the archaeological and faunal records which are marked by behavioural, cognitive (Acheulean specialisation/expansion) and morphological (encephalisation) innovations within the genus*Homo*. Unfortunately, the EMPT African hominin fossil record is scarce and poorly correlated with the archaeological record. Here we present faunal and chronometric data of a newly discovered EMPT site in West Turkana: Kanyimangin.

In August 2017, the Trans-Evol Project started fieldwork in the floodplain of the Kerio River (Turkana Basin, Kenya), identifying a new palaeontological and archaeological locality. Kanyimangin is located within the Kalabata river (a tributary of the Kerio river) circular anomaly, where *ca.* 15-meter-deep sediments are preserved from erosion by a series of five sandstones. Although there has been almost no focussed local palaeontological and geochronological study, sediments in that area were believed to be older than 3.7 Ma. However, using combined palaeomagnetism and bio-chronological approaches, we obtain an age estimate between 0.90 and 1.19 Ma.

Kanyimangin has yielded substantial lithic (n=344) and faunal (n=2155) assemblages originating partly from buried contexts. The latter comprises 212 individual specimens (NISP) distributed across 20 taxa. The faunal spectrum is composed of both aquatic and terrestrial taxa, including: *Palaeoloxodon (Elephas) recki* cf. *recki*, *Panthera* sp., *Hyaena hyaena*, *Equus grevyi*, Rhinocerotidae, *Kolpochoerus (limnetes) heseloni*, *Phacocoerus* sp., *Hippopotamus amphibius*, *Syncerus caffer*, *Aepyceros melampus*, *Alcephalus buselaphus*, cf. *Nanger granti* and a Renducini as well as the narrow-snouted *Euthecodon brumpti,* a broad-snouted crocodile, turtles/tortoises, snakes, fish and amphibians.

Palaeomagnetic results reveal a normal polarity for the archaeology-bearing sandstone and evidence for a subsequent period of reverse polarity. Together with the presence of *Palaeoloxodon recki* cf. *recki* recovered from the same sandstone, this suggests a Matuyama age for the site after the Olduvai subchron. To date, most faunal remains were recovered from survey, which limits their biostratigraphic potential; however, the presence of well-fossilised *Phacochoerus sp.* and *Alcephalus buselaphus* specimens recovered on the surface of the archaeology-bearing sandstone equally suggests a Jaramillo (1.06–0.90 Ma) or Cobb Mountain (1.19 Ma) age for the site.

The roots of Acheulian Large Cutting Tools duality: A morpho-technological view from 'Ubeidiya, Israel

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The site of 'Ubeidiya, situated in the Upper Jorden Valley, Israel, and dated to roughly 1.5 MaBP, is one of the earliest Acheulian sites outside Africa. Rich lithic assemblages recovered from multiple stratigraphic units, alongside faunal remains and environmental evidence provide the basis for reconstructing numerous aspects of the subsistence, technological and cultural behaviors of Early Pleistocene hominins. The lithic assemblages of 'Ubeidiya show a significant morphological and technological difference from all later known Levantine Acheulian assemblages, being reminiscent mostly of Early Acheulian assemblages from East Africa. Recently, a renewed morpho-technological study combining high-resolution, objective 3D geometric morphometric with traditional technological analyses has been conducted on a sample of Large Cutting Tools (LCTs) from the site. The results corroborate the morpho-technological difference between the 'Ubeidiya LCTs and those recovered from later Acheulian assemblages in the region, while providing a quantitative characterization of the nature and magnitude of these differences. Furthermore, an in-depth analysis of the 'Ubeidiya material demonstrates a clear separation between two classes within the wider LCT category – one with two bifacially worked faces (i.e., handaxes) and the other with more than two, but not all necessarily worked faces (i.e., trihedrals, multihedrals, picks). This separation can be seen on both the morphological and the technological aspects. The results show that the technological paths leading to each of these classes were separated at a very early stage of the *chaîne opératoire*, namely a decision made when the raw material was selected. Several lines of evidence support the notion that this selection was a result of a deliberate decision rather than random chance. The behavioral pattern of intentionally producing two (or more) morpho-technological classes of LCTs is well known from later Acheulian assemblages and was shown to be supported by complex and well-developed cognitive capacities. The results obtained in the current study show that these capacities were already well established in the minds of hominins by the time of 'Ubeidiya.

Differentiated technical behavior in the late Acheulean site of Jaljulia, area D (Israel).

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The archaeological record of the Levant reveals important changes in the techno-economic organization of late Acheulean groups. Well-dated and large-scale excavations are though rare.
In this paper, we present the results of a global technological analysis of both debitage and shaping *chaînes opératoires* from the area D of Jaljulia, dated to ca. 500 ka. The site, located in the central coastal plain, has yielded several areas rich in lithic material excavated in 2016-2017 by the IAA and Tel-Aviv University. Area D, the oldest one, yielded 24,146 flint artifacts including many bifaces and a rich flake production.
The study of the bifacial pieces shows a priority focused on the distal part of the pieces that indicates a higher technical investment that decreases as it reaches the bottom. This result in higher morphological variability of the pieces that do not reflect lower technical skill of the knappers, but is related to the goals of the knapping activity. A limited range of morphologies of the distal part and the use of blanks of different sizes indicate the search for specific goals in the production and illustrate the diversity of tools produced.
On the other hand, the flaking *chaines opératoires* are diverse, including Levallois (*Lato sensu*), Discoid, S.S.D.A. and Cores-on-Flakes. While hierarchized systems (mainly referred to as part of “Prepared Core Technologies”) are present in small proportions in the late Acheulean Levant, in area D of Jaljulia they represent around 30% of the global flake production.
Flint types used are exclusively local, however, specific blanks and flint types were selected for different production goals. Shaping was preferentially made on brecciated Mishash flint, when more fine-grained varieties were used for flaking, together with Turonian flint. Even within flake production, the hierarchized concepts are applied to higher quality cobbles/pebbles.
Finally, double-patinated items, recycled pieces (including bifaces with preferential removals) and ambiguous pieces indicate a possible continuum between the production systems.
In the broader context of the Levantine Acheulean, Jaljulia offers an original combination of technical choices that reflect important behavioral changes.

Stratigraphy, geochronology and paleoecology at the Earlier Stone Age coastal sites of Mormolo, Benguela Province, Angola

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Mormolo H8-3, an open-air site discovered by L.J. Pais Pinto in the 1970s, is located on the +100m high raised beaches of the Benguela Province (Angola). The Benguela Province is famous for the good preservation of the coastal sedimentary deposits and their prehistorical bearing over a 50 km strip – especially in a massive Red Sand deposit. The base of this deposit is composed of several layers of Stone Age artefacts. However, the raised beaches prehistorical content remained poorly investigated – in the exception of Dungo IV site where excavations, geochronological and lithic analysis were conducted. In 2021, in the framework of the Mormolo Archaeological Project, the new investigations conducted in the neighboring +100m raised beach of Mormolo aimed to build an archaeological map and to work on an extended network of Earlier Stone Age sites estimated to be >500 ka. More specifically, our work aimed to provide key data to study the earliest human occupations at local scale on the on coastal territories and mobility at the onset of the Middle Pleistocene. We initiated the excavations of two localities: Mormolo H8-3 and Mormolo H8-4. The former has preserved faunal vertebrate and invertebrate (sharks, crabs and shells) whereas the latter is interesting for its high density of lithic remains.
Here, we present the first results by providing a new stratigraphic and sedimentological framework as well the taphonomy geochronological (ESR dating) and marine fauna results. We discuss 1/the sites setting in the broader context of Earlier Stone Age open-air sites in Sub-Saharan Atlantic Africa, 2/ the potential of the Benguela Province sites to provide new evidences on the antiquity of the relationship human-coastal environments and 3/ the relationship hominin groups/coastal territory.

A Mode 2 site dated to MIS 14-13 in the fringes of the Sahara: Oued Rabt, Eastern Morocco

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Eastern Morocco is well known for its Late Pleistocene cave records. However, until recently, the open-air older record has been scarcely investigated. A cooperative project initiated in 2006 is aimed at investigate the entire Pleistocene open-air sites in the area to test the human settlement in a region close to the well-known Early and Middle Pleistocene archaeological and palaeontological sites of the Moroccan Atlantic seashore and of the Haut Plateaux of Algeria.
Here we present Oued Rabt, a precisely dated Middle Pleistocene Mode 2 site in the Aïn Beni Mathar – Guefaït basin (ABM-GFT). This basin corresponds to the westernmost area of the Haut Plateaux and Salt Lake region of Maghreb, a physiographic unit placed between the Mediterranean and Saharan domains and isolated from the Atlantic coast. Through different proxies we place this archaeological settlement in its ecological setting and discuss its role in the human settlement in the region and importance for the Moroccan and Maghrebian Mode 2 record.

Will the Western African Pleistocene record ever be able to contribute to the interpretation of the African Acheulean(s)?

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In West Africa, the chronology, population dynamics and technical behaviour for the Early Stone Age are probably the least understood of the continent for this time period. The Oldowan seems to be virtually absent, and the oldest known industries are designated as Acheulean or Sangoan, depending on the presence of bifacial tools and cleavers or picks respectively, although the Acheulean is generally considered to be older. The earliest dates available so far do not pre-date 300 ka for either of these cultural units, and the few available dates are considered to require revision. Among the main issues is the meager amount of *in situ* sites and the environmental conditions unfavourable for Pleistocene sedimentary sequences to be well preserved, thereby also affecting dating methods' efficiency. However, in the framework of the international program "Human Populations and Palaeoenvironement in Africa- Falémé project", we are currently conducting intensive research on two well preserved *in situ* Acheulean sites located in eastern Senegal, at the Malian border. These two sites, located some 10 km apart, show different site-functions as well as technological and typological divergences between the industries, suggesting the succession of two Acheulean occupations in the area. Efforts to date the sedimentary sequences by OSL and ESR are ongoing, involving methodological developments adapted to the West African Middle Pleistocene sedimentary context. Here, we present these sites and our combined approaches to address the persistent backlog of Early Palaeolithic studies in West Africa, particularly with respect to the Middle Pleistocene Acheulean record. The overall objective is to ensure that data on West Africa finally contribute to an integrated vision of the dynamics at work on the continental scale, at least on the basis of lithic material and a better chronology, since the Pleistocene fauna remains to this day an even greater enigma in this region.

Session 130: Advancing paleoscience in underrepresented regions: promoting records of past socio-environmental systems in the Global South and beyond

Long-term stability and change in Mozambique's savanna woodlands

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Mozambique's highly diverse savanna woodlands have developed hand-in-hand with human activity over millennia. Despite the long history of human interaction with these ecosystems, currently they are under threat from human-induced climate change, fire regime change, unsustainable logging and agricultural demand from rapid population growth. Governments and non-government organisations are responding to these threats by implementing policies and practical measures to restore Mozambique's ecosystems. However, these efforts could be misguided in the absence of ecological baselines. We studied the Holocene history of vegetation in Inhambane Province to provide a long-term context for restoration and conservation. Our data contradict the view that this region was a coastal forest prior to recent deforestation, showing instead that species-rich savanna woodland has been a persistent feature. The dominant tree species in today's vegetation are not the same species that prevailed in the past. Fire has been a key disturbance in savanna woodland dynamics for at least 7000 years. These data indicate a dynamic system that evolved and continues to evolve in response to climate and humans. Efforts to restore dense coastal forest in these areas of ancient savanna woodland could lead to biodiversity loss and the erosion of the irreplaceable cultural values and sustainable livelihoods that these ecosystems have supported for millennia.

Climate changes inferred from sedimentary biomarkers during the Pleistocene-Holocene transition in central Chile (~34ºS)

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The ancient Tagua Tagua Lake (ATTL) is one of the few places in South America where evidence for a direct megafauna kill site is linked to a sedimentary record of environmental change. The ATTL record is thus ideal for assessing Coupled Human and Natural Systems during the Pleistocene-Holocene transition (PHT). In this work, we carried out a climatic and environmental reconstruction based on sedimentary biomarkers of the archaeological site Taguatagua 3 that indicates more arid and cooler conditions during the late Pleistocene than previously described. Our multi-proxy record spans the last ~20 ka cal BP in a 2.8 m deep sedimentary sequence (14 AMS 14C dates) and was sampled for bulk geochemical indicators, grainsize, n-alkyl leaf waxes (n-alkanes, n-alkanols, fatty acids), sterols, branched glycerol dialkyl glycerol tetraethers (brGDGTs) and calcite isotopic composition (δ18O and δ13C) from carbonate-rich sections. Lipid biomarkers show higher abundance of n-alkanes and n-alkanols compared to fatty acids. Mean annual air temperature (MAAT) estimated using brGDGTs show average values of 16.5ºC, similar to temperatures of sedimentary pigment-based reconstructions in other Late Holocene records from central Chile. n-Alkane, n-alkanol and sterol time series showed that the greatest increase coincided with wet events (i.e. estimated by δ18O carbonate and δD in n-alkane) during the PHT and the Early Holocene. Major shifts occurred at ~12.5-12, ~11.5-11, and ~10.5-10 ka cal BP characterized by the onset of wetter conditions. Additionally, we detected a statistically significant cold pulse between ~11.7 and 10.5 ka cal BP that corroborates previous results. The ATTL record suggest important changes in the strength of the South Pacific anticyclone, synchronous with large-scale atmospheric changes during Younger Dryas, but persisting 500 years after the onset of the Holocene.

Holocene hydrological changes in southeastern Mozambique

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Climate changes are one of the drivers responsible for lake hydrological changes. Thus, the InMoz project aimed to understand southeastern Mozambique's hydrological changes through the Holocene. This is particularly relevant because there are few paleoclimate studies in this region of the globe. The study of paleohydrological changes in Mozambique is essential to better understand regional and global patterns of climate change and the impact of their dynamic on human populations (i.e., settlement pattern and dispersal). To do so, we collected a ca. 6 m long sediment core on a Mozambican coastal lake, and we analyzed it using a multi-proxy approach (e.g., sediment texture, geochemistry, diatoms, ostracods, mollusks and foraminifera). The analyzed proxies showed that from 7200 to ca. 4100 cal BP the lake water varied between salt and freshwater, because of marked seasonality during a warmer and wetter climatic phase than today. Between ca. 4100 and 1200 cal BP, the lake water became mostly brackish. From ca. 1200 cal BP to the present, it was mostly freshwater. Throughout the record, the proxies indicate that the lake water was alkaline and there was an increasing trend towards eutrophic conditions. Thus, the lake's hydrological shifts were likely driven by an increasingly moist climate in the catchment area and the introduction of agricultural activities in the region, reflecting long-term interactions between humans and the surrounding environment. This work was financed by the Portuguese Science Foundation through project PTDC/HAR-ARQ/28148/2017 and contract CEECINST/00146/2018/CP1493/CT0002.

Vanuatu cultural landscapes across time and space

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Islands are emblematic cases of anthropogenic impacts on ecosystems. First human settlements in Remote Oceanic Islands came along with major landscape modifications. Which factors led to the failure or the establishment of a sustainable human-ecosystem interaction remains an open question. Reconstructing past human activities can help to retrieve information on the environmental responses to different degrees of change. The archipelago of Vanuatu is a key area for the recent human colonization of the Pacific (~3000 years ago), which came along with major landscape modifications and is vulnerable to extreme events and climatic changes, past, present, and future. Through the multi-proxy analysis of lakes sediment cores from the archipelago of Vanuatu, we provide paleoclimatic and paleoenvironmental reconstructions, combining geochemical tools based on biomarkers with sedimentological and palaeoecological analyses in sites with different degrees of archeological knowledge. High-resolution radiocarbon dated sedimentological records from the islands of Efate, Espiritu Santo, and Ravenga are presented and confronted against different times and modes of human occupation. Environmental reconstructions are validated with local knowledge and memories to understand indigenous communities' resilience to environmental changes observed in the cores such as extreme events (volcanic eruptions, droughts, cyclones). Tracing past land-use and climate change, on remote Pacific islands, and the response of local inhabitants to these changes highlights the links between cultural activities, such as agricultural practices, and the environment and contribute to identifying key factors related to the ecological resilience and the adaptive capacity of socio-ecological systems in changing environments.

Understanding flood histories and anthropogenic impacts on lakes in South Asian mega deltas

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Climate change and anthropogenic impacts on freshwater ecosystems in South Asia exacerbate issues caused by dynamic, and densely-populated river mega deltas. These ecosystems face impacts from changes to their hydrology, alteration of seasonal monsoon patterns, urbanisation, industrialisation and land-use change. Floods derived from seasonal rains or extreme weather events have historically brought benefits as well as hazards. South Asia is highly vulnerable to projected climate changes and its associated impacts, but the uncertainty in changes to severity and frequency of floods, as a result of a paucity data of flood data, makes it difficult for policy makers to plan for management of and development of adaptation strategies for vulnerable freshwater ecosystems. Moreover, many societies are dependent on the services provided by lakes and other waterways in these systems and a need to understand the impacts they are having to work toward sustainable usage. Palaeolimnology is well-placed to put flooding and anthropogenic impacts on waterways in context and provide much needed long-term data series that is lacking in this global region. In this study, we use multiple sediment cores recovered from oxbow lakes on the Ganges-Brahmaputra-Meghna Delta spanning India and Bangladesh. Chronologies have been established using ^{210}Pb radiometric dating and multi-proxy analysis including grain-size, magnetic susceptibility, XRF, and pigments was conducted to detect flood histories and anthropogenic impacts. Our results are the first to put climatic and anthropogenic impacts in context with the limnological history of these important social-ecological mega-deltas.

Understanding human-driven ecosystem change in a rare Malaysian flood pulse wetland (Tasik Chini)

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Tropical areas are undergoing rapid environmental change as a combined result of climate change and human impact on the landscape, which significantly threatens the quality and biodiversity of freshwater ecosystems. Tasik Chini is a flood pulse wetland located in Peninsular Malaysia and is one of the few lake basins in the low-lands of this region. The site is of great ecological importance and designated a UNESCO Biosphere Reserve. In recent years, the natural vegetation of the catchment and surrounding area has become increasingly influenced by forest clearance, oil palm plantations, mining, logging, and tourism, which have resulted in pollution, soil erosion, and external nutrient loading to the lake. The main outflow river has also been dammed to help sta-bilise the water level. Together, these activities have changed the hydrological balance of the lake, influenced biodiversity causing species and habitat loss, and led to eutrophication. To understand the influence of major changes in catchment land use on the lake and to investigate the key drivers of ecosystem change, sediment cores have been recovered from across Tasik Chini. The first core is from a site adjacent to a tourist resort, the second core is from a basin situated close to mining activity, and the final core was retrieved from a site furthest from major catchment disturbance. An established chronology based on ^{210}Pb dating shows each gravity core covers back to the late 19th century and spans the transition to enhanced human impact within the catchment. Organic geochemistry (%C, C/N, carbon isotopes, Rock-Eval pyrolysis), diatom assemblage, elemental concentra-tions, and sedimentary pigments have been analysed on each core to reconstruct past environmental conditions. Combined with a longer sediment record from the lake dating back to 4.8 ka, data show how past variability compares to recent anthropogenic-induced environmental change and define how different catchment distur-bances have contributed to ecological change at this internationally important wetland site. This information is vital to assess ongoing human impacts at the site as a means to provide science-based management strategies and thereby counter the main drivers of ecosystem degradation.

Reconstructing biogeochemical cycling and primary producer community change at Hoa Binh Reservoir, Vietnam

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The Hoa Binh reservoir is a major impoundment upstream of the Red River Delta (RRD), Northern Vietnam. Since its construction in 1988, downstream mean discharge has reduced in tandem with suspended sediment transport, which together with sea level rise, have contributed to an increased risk of saline water intrusion in the RRD. Palaeoecological reconstructions from Hoa Binh reservoir, dated radiometrically, document the transition and stabilisation of the lake since its creation from river impoundment in 1988. First changes in sediment composition are identified after c. 1997, when an increase in organic content (Rock Eval) and $\delta^{15}N$ compositions takes place. After c. 2004 there is evidence of increasing Fe_2O_3 deposition, concomitant with an increase in sedimentation rates. Algal pigments also show a general increasing trend after 2004, with prevalent concentrations of cryptophytes (alloxanthin), siliceous algae (diatoxanthin), chlorophytes (lutein) and cyanobacteria (canthaxanthin). Further increases of these algal groups are documented post c. 2010 with sedimentary preservation indicators (Chl *a*:*a* phorbins) also showing an increasing trend; the latter possibly reflecting the increases in sedimentation rates and organic carbon fluxes in response to cultural eutrophication. Similarly, diatom concentrations (*Aulacoseira* and *Cyclotella species*) show a sharp increase after c. 2010, pointing to a more eutrophic environment and changes in lake stratification.
%C shows a gradual increasing trend since dam implementation, with a decline in $\delta^{13}C$ signatures (from c. −24 to −29‰), with C/N values (<10) indicating that throughout the core carbon is sourced from aquatic productivity. Microcystin occurrences also indicate the presence of cyanotoxins throughout the sediment record (reaching up to c. 50 ng g^{-1} OC^{-1}) with highest fluxes being recorded in the surface sediments (>750 ng cm^{-1} yr^{-1}). This is concomitant with the appearance of *Cyclotella stelligera* after c. 2016. Together, the multi-proxy stable isotope, geochemical and algal analysis adopted in this study demonstrate the recent impact of increased aquaculture in the Hoa Binh reservoir, which has triggered the increased proliferation of harmful algal blooms, eutrophication and an increase organic carbon fluxes to the sediment record.

Fossil-CO2 have been detected in tree species in Central Amazon basin due to mining operations and increased use of rivers as trade routes

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Tree rings has been widely used for atmospheric radiocarbon (^{14}C) calibration purposes, including those associated with the post-1950AD (nuclear era). However, tree ring ^{14}C records have been limited along tropical latitudes. Recently we obtained precise ^{14}C dates in tree rings (1937 to 2007) of the parenchyma-rich *Hymenolobium petraeum* tree species from the Central Brazilian Amazon (Porto Trombetas, 1°S, 56°W). Radiocarbon results showed that the *H. petraeum* atmospheric ^{14}C signals surrounding the bomb peak (1950–1971) are in agreement with the broader changes associated with reported values of the Southern Hemisphere ^{14}C curve based on a stand-alone tree ring ^{14}C record of *Tectona grandis,* Indonesia. After 1980, *H. petraeum* atmospheric ^{14}C signals reveal local fossil fuel-related contributions that are most likely from heavy-duty diesel engines used by mining operations as well as those from shipping activities by cargo ships in the Amazon River downstream and estuary areas. The local dilution of atmospheric $^{14}CO_2$ captured in wood tissue and measured by high-precision ^{14}C accelerator mass spectrometry coincided in time with the implementation and expansion of the mining activities and trade networks that uses the Trombetas and Amazon rivers to handle most of export shipments of country’s ore, soybean and corn by transnational business giants. Thus, atmospheric ^{14}C variability in the Central Amazon has a wide range of natural and anthropogenic sources, and must be monitored closely.

Session 133: Unravelling Mediterranean sensitivity to past rapid climate variability

Expressions of Holocene Rapid Climate Changes in eastern Mediterranean proxy data

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During Holocene Rapid Climate Change (RCC) cold events, reflected in Greenland non-seasalt K^+ time series, Mediterranean surface-water temperatures were reduced, and deep-water ventilation changes occurred. This indicates that the basin was affected intensely and persistently enough to overcome the considerable inertia of its deep and extensive water mass. We explored the impact of cold winter events on the eastern Mediterranean with an idealised model that uses Greenland ice-core K^+-based changes in the annual frequency of 10-day cooling events with increased wind speeds (based on modern observations), superimposed upon the winter half-year of a regular (sinusoidal) annual cycle. The model resolves evaporation, precipitation, temperature, salinity, and stable oxygen isotopes. It considers only cold anomalies relative modern conditions, and not intervening events that may be warmer than present. It also ignores long-term (orbital) changes. Reconstructed sea-surface coolings agree well with observed coolings, both in timing and in amplitude. Concomitant salinity increases are simulated, in agreement with density changes that can be inferred from deep-water ventilation during the cold anomalies. The model simulates strong increases in negative degree days at 2 km altitude in Crete, which agree with reports of persistent snow cover in high Cretan mountains during the Little Ice Age. Snow-line drops are simulated down to altitudes of 770 m for the Levant, consistent with snow events observed in Jerusalem (787 m) during modern cold outbreaks over the eastern Mediterranean. Modelled precipitation increased by similar amounts in Crete and the Levant, and $\delta^{18}O$ of precipitation decreases in both locations, albeit by different amounts. Hence, the $\delta^{18}O_p$ changes do not seem to reflect a classical "amount effect", but instead changes in the mass-balanced mixing between the amount of moisture held in incoming air (lower for colder events), and the amount of moisture added due to evaporation from the sea (greater for colder events). The modelled $\delta^{18}O_p$ changes agree well with high-frequency $\delta^{18}O$ at Jeita Cave, Lebanon. Overall, the experiments indicate that a more rigorous quantitative framework is needed for interpreting the varied expression of abrupt climate events on Mediterranean proxy records because compensating effects can lead to a variety of counter-intuitive impacts.

Opposite trends of tree cover changes in the Mediterranean Basin around the 4.2 ka BP event

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In the Mediterranean Basin the so-called “4.2 ka BP event” is recognized as a period of overall climate instability connected to hydrological changes, although the timing, nature, and expression of climate change were not uniform. Tree cover changes in pollen records are an excellent candidate proxy for reconstructing the geographical expression of moisture changes over time.

To investigate the response of vegetation to climate variability during the 4.2 ka event, we compiled a pollen database of 486 sites from all over the Mediterranean Basin and surrounding regions. Our aim was to verify whether general trends of increases/decreases in tree cover are detectable throughout the Basin and whether they show any spatiotemporal pattern. We considered variations in Arboreal Pollen (AP) percentages before and after 4.2 ka BP as a simple, uniform, and direct proxy for past tree cover change. The comparison of AP% before (4.5 ka BP), at the onset (4.2 ka BP) and at the end (3.9 ka BP) of the 4.2 event suggests that coherent increases and decreases in tree cover occurred in different areas of the Mediterranean Basin.

Between 4.5 and 4.2 ka BP, a forest decline is observed in NW Iberia, in Sicily, and the southern Italian Peninsula, while in Mediterranean Iberia, Morocco, and the Levant, there was a moderate increase in tree cover. In a wide belt including France, N Italy, Corsica, and Sardinia, the northern Balkan Peninsula, and the Caucasus, there were minimal variations.

Between 4.2 and 3.9 ka BP, an increase in forest cover is observed in NW Iberia, in Sicily, and the southern Italian Peninsula, while in Mediterranean Iberia, Morocco, and the Levant an opening up of forests occurred. No statistically significant changes in AP% are recorded in the geographical belt stretching from France to the Caucasus.

These results allow to circumscribe regions sensitive/unsensitive to hydrological changes across the Basin and to highlight consistent spatiotemporal patterns of bioclimatic change. Tree cover variations revealed bioclimatic processes of opposite polarity in different regions of the Basin, suggesting the occurrence of a sign-switching pattern centred at 4.2 ka BP.

Deglacial and Holocene changes in Mediterranean Thermohaline Circulation: A joint perspective from Eastern and Western basins

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The dominant arid climate conditions over the Mediterranean (Med) control water properties and the formation processes of intermediate and deep water masses. Deep convection cells occur in both the E- and W-Med basins and there are interconnected through the intermediate waters mostly formed in the easternmost area of the Med. During last deglaciation and Holocene periods both E- and W-Med had experienced periods of major disruptions in deep convection. The last organic layer (ORL1) formed in the W-Med during the deglacial period and later the last sapropel (S1) in the E-Med. Both enhanced productivity and enhanced stratification are regarded as the causes for the two events but responding to different drivers, the deglacial freshening in the case of the ORL1 and the African monsoon flooding for the S1.

Here we present U/Mn ratios measured in the foraminifera diagenetic coatings from sediment cores from both E- and W-Med. The nature of this proxy, sensitive to oxygen water content, allows its application in a wide range of oceanographical/oxygen conditions, a situation that compromises other proxies whose carrier is limited by the changes in oxygen content. This approach allows us, by the first time, to compare the oxygen evolution of individual basins and at different water depths by means of the same tool. The obtained results indicate the deglacial development of an intense minimum oxygen zone in the W-Med associated to the LIW which extended down to at least 950m in association with the ORL1 formation, highlighting that the E-Med could also had had an important role in the development of this ORL1. During the Younger Dryas a re-ventilation process of the W-Med interior started at around 900m and evolved upwards and downwards to fully develop at shallower and deepest depths (300 and 1840 m respectively) at the onset of the S1 in the E-Med. Changes in the thermohaline system of the E and W-Med were closely related but with opposite sign in their response during critical events such as the S1.

Variabilities in Mediterranean water circulation across the Holocene and the last interglacial humid periods

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Projections of the Mediterranean thermohaline circulation generally indicate stagnant circulation by the end of the 21st century, although the amplitude of the changes is variable with models. To evaluate the sensitivity of the Mediterranean circulation to different forcing, we studied the intermediate and deep water states during Holocene and the last interglacial when excess freshwater inputs had promoted the deposition of organic-rich layers "sapropels" in the eastern basin. The deposition of sapropels S1 (6.1-10.5 ka) and S5 (centred around 125 ka) was related to strong stratification of water column and consequent reduced ventilation. We reconstructed seawater neodymium isotopic compositions ($^{143}Nd/^{144}Nd$ or ε_{Nd}) by analysing authigenic fractions from the western (ODP site 977 in the Alboran Sea and PRGL1-4 in the Gulf of Lion) and eastern (SL95 in the Gulf of Sirte) basins. To evaluate hydrological perturbation, planktonic foraminiferal oxygen and carbon isotopic compositions ($\delta^{18}O$ and $\delta^{13}C$) were analysed for eastern basin cores (SL95 and MD04-2724 in the Levantine Sea).
The new authigenic ε_{Nd} records from the western basin showed limited variation from -9.3 to -8.0 for the study periods. In contrast, the eastern basin core presented a marked ε_{Nd} increase during sapropel periods from about -8 up to -4.6 with higher values during S5. Since the western ε_{Nd} range is comparable with the present-day water value, reconstructed zonal seawater ε_{Nd} gradient was enhanced during sapropel depositions. The new planktonic foraminiferal $\delta^{18}O$ ranged from -0.9 to 4.8‰, and -2.3 to 3.3‰ over the past 140 ka for SL95 and MD04-2724, respectively. Both records showed a marked decrease in foraminiferal $\delta^{18}O$ and $\delta^{13}C$ that started prior to S1 and S5. A 6-box model calibrated for the modern seawater ε_{Nd} suggests the observed increase in zonal ε_{Nd} gradient can be produced by reduced circulation in the eastern basin and more radiogenic Nd inputs including enhanced Nile river particle loads and/or longer contact with labile detrital sediments due to stagnant circulation. The relationship between the hydrological perturbation suggested by planktonic foraminiferal stable isotopes and authigenic ε_{Nd}records will be discussed using compiled data.

Abrupt and persistent shutdown of the thermohaline forcing during MIS5e in the Adriatic Sea: insights from shallow-water sapropel sediments

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The orbitally-driven anoxia that cyclically occurred in the Eastern Mediterranean Sea (EMS) is one of the strongest evidence showing how climate change and thermohaline forcing are connected to each other. Most of the focus in sapropel studies has been traditionally placed on deep sediments where the sapropel is indeed well-expressed yet far from the margins where dense water forms. To provide a shallow-water perspective, we investigated the Sapropel S5 on the Adriatic shelf (borehole PRAD1-2; 185.5 m water depth) during MIS5e. This archive is strategically located in a region where the dense cold-water interacts with the seabed before cascading off the margin. Zr/Rb (grain size) and Mg/Al (sediment provenance) ratios were used to resolve the degree of dense water export while the extent of deoxygenation was reconstructed through trace elements (U, V, Mo, Sb) and benthic foraminifera abundance. Stable isotopes of foraminifera ($\delta^{18}O$,$\delta^{13}C$) and organic geochemistry data (TOC, alkenones) provided additional information about water column and sediment properties. Finally, we synchronized our record from the margin with other deep sapropel S5 (LC21, 971A, KS205 and 967) to harmonise shallow and deep archives over a common time scale.

Collectively, our results show that the shutdown of the convection over the margin was an abrupt event (ca. 128 ka BP) that occurred in a few centuries. Pre-sapropel deoxygenation started ca. 131 ka BP without signs of weakening in the dense water formation; this puts forward the hypothesis that pre-sapropel changes were driven by trophic conditions possibly linked to sea level rise and advection of nutrient-rich Atlantic waters. Weak dense water formation lasted for about six millennia while the redox conditions changed throughout this period suggesting a scenario of steady stagnation superimposed to variable productive conditions. Overall, our results do not support the hypothesis that anoxia requires a long prelude of deep-water stagnation driven by the post-glacial inflow of relatively fresh deglacial Atlantic waters; rather our data highlight the abrupt nature of convection that responds to short-term climate variability. In our presentation, we further discuss the thermohaline shutdown in terms of freshening and general winter warming compiling evidence from the literature.

Abrupt Mediterranean storm track reorganization and cooling during the mid-last Interglacial at Peqi'in Cave (Israel)

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The mid last interglacial (mid-LIG; ca. 126 ka) was punctuated by reductions of North Atlantic Deep Water (NADW) ventilation and North Atlantic Sea Surface Temperature (SST) cooling. Associated with these marine events are evidence of terrestrial cooling and climate change in speleothems from central and southern Europe. Here we reconstructed a temperature record from organic compounds (TEX_{86}) in a speleothem at Peqi'in Cave (northern Israel) and show that the mid-LIG cooling event extended to the eastern Mediterranean. The temperature record exhibits a climate optimum during the early-LIG (128 - 127 ka) followed by a significant irregular cooling of up to 3-4°C (126 - 123 ka) and then a recovery (123 - 118 ka). However, there is a lack of clarity on how mid-LIG oceanic changes in the North Atlantic are connected to the eastern Mediterranean cooling and reconstructing the atmospheric configuration is key to understanding this connection. We investigated atmospheric configuration changes during the LIG by extracting small volumes of paleo-rainfall trapped in the speleothem crystalline structure (fluid inclusions), measuring the stable isotope composition ($\delta^{18}O$ and δD), and then reconstructing a high-resolution *d-excess* ($\delta D - 8\times\delta^{18}O$) record. The Peqi'in *d-excess* record reveals shifts in the paleo- Eastern Mediterranean Meteoric Water Line (EMMWL) which argue for moisture uptake changes in the Mediterranean that are also coupled with the LIG temperature changes. The *d-excess* decreases from an early-LIG peak at 35‰ to below 20‰ at ca. 126 – 122.5 ka (minimum 16.5‰) and then increases after ca. 122 ka to 26 ‰. To explain these *d-excess* trends we determined the long-term contributing factors for modern rainfall *d-excess* in Israel (for rainfall events at Soreq Cave between 1995 and 2021). Extending these results to the LIG suggests a wintertime dominant storm track reorganization, characterized by a shift from meridional (northerly) to zonal (westerly) trajectories, occurred in the eastern Mediterranean from the early- to mid-LIG. The shift to zonal trajectories with clear North Atlantic origin during the mid-LIG underpins a mechanism for facilitating cooling in southern Europe and the eastern Mediterranean.

Changes in Atlantic Intermediate Water circulation and Mediterranean Outflow during Termination V in the Southwest Iberian Margin

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The size of the Northern Hemisphere Ice sheets reached one of the highest levels during Marine isotope stage 12. Their collapse during Termination V caused a deep impact on the Atlantic and Mediterranean thermohaline circulation. Large amounts of freshwater were delivered from the Eurasian and Laurentide Ice sheets to the north Atlantic and the Mediterranean, causing a rapid sea level rise and a reorganization of Atlantic and Mediterranean Meridional Circulations. To better understand the impact of these changes we studied stable isotope records in planktic and benthic foraminifers in IODP Site U1389 in the Gulf of Cadiz (SW Iberia, NE Atlantic), ODP site 977 (SE Iberian Margin, Western Mediterranean) and site PRGL1 (NW Mediterranean). Planktic foraminifer assemblages were also analyzed to estimate sea surface temperature and changes in surface seawater d18O in the Atlantic inflow and the western Mediterranean. A significant meltwater event is recorded at the onset of Termination V in the SW Iberian Margin, synchronous with the arrival of cool, subpolar low salinity surface waters. The imprint of freshwater is also recorded in the Mediterranean surface waters both in the westernmost and NW Mediterranean, as well as in the Mediterranean Outflow. In the NW Mediterranean, this event is related to a rapid sea level rise recorded by a sudden change in the sedimentation linked to the landward retreat of Rhone deltaic system in the Gulf of Lion.

Session 134: How Absolute and How Relative: Challenges and Resolutions Associated with Applying Dating Techniques in the Quaternary period

Amino acid geochronology: advances and limitations in bivalve shells

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The SEACHANGE project is a multidisciplinary project that aims to reconstruct marine ecosystems prior to and after significant cultural transitions. For robust geochronology, radiocarbon dating of organic material, cross-matched and cross-dated sclerochronology (dating of hard tissues of shells) are employed. Cross-matched floating sclerochronologies (not precisely calendar-dated) can provide annual resolution records spanning decades to as much as 500 years for the longest-lived shells. Developing this record requires visually and statistically comparing growth ring width patterns (cross-matching) across numerous samples. Such an endeavour can be hugely time consuming and therefore needs to be targeted appropriately, especially when dead-collected samples are of unknown antiquity. Radiocarbon dating can be a very precise technique, but it is not always economically viable, especially for a large number of samples (>2,000), and it requires correcting for the marine reservoir effects.
Here we explore the potential for range-finding age estimates of individual dead shells by amino acid (AA) geochronology. AA dating is a relatively fast and cheap technique, which can be used to constrain the time period for any floating sclerochronologies. Previous work on the intra-crystalline protein fraction from calcareous biominerals has resulted in a robust dating method for the Quaternary period. High precision can be achieved in warm environments, for example, cross-dated Porites coral skeletons provided precisions ±24 years across different colonies in samples from the last 150 years.
In addition to the already known caveats of AA geochronology, bivalve shells also present the additional complication of having different microstructures. These have shown significant but consistent variation in AA composition between the microstructural layers, meaning that targeted sampling is necessary to establish a robust and reproducible method for dating bivalve shells. In SEACHANGE, aragonitic Arctica islandica and calcitic Ostrea edulis are targeted in the first instance to constrain mediaeval and Mesolithic-Neolithic shell middens, respectively, showing the range and resolution in dating. These preliminary results indicate that the inner portion of the outer shell layers (iOSL) of A. islandica and foliated layer of O. edulis should be targeted for AA geochronology.

Advances in amino acid dating of Pleistocene mammalian tooth enamel

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Directly dating mammalian remains is extremely difficult beyond the limits of radiocarbon dating (~50 ka). One possible direct dating method is to use the predictable breakdown of proteins and amino acids in biominerals that contain closed-system organics. This has been a powerful tool for age estimation in calcium carbonate biominerals (back to ~2.5 Ma). It's application to mammalian tooth enamel has been challenging but we have developed a novel method to target a proteinaceous fraction in enamel protected within the biomineral crystals (the intra-crystalline fraction), which has alleviated difficulties associated with contamination, leaching and environmental influences.

The extent of intra-crystalline protein degradation (IcPD) in elephantid enamel has been tested against known age material from the British Isles, the East European Plain and the Mediterranean, showing a strong correlation between IcPD and age. It is therefore now possible to provide direct age estimates for unknown age elephantid material from these regions. Analysis of horse and bison remains from several Middle Pleistocene sites, enables investigation into the taxonomic differences in the rates of amino acid breakdown.

We are currently extending the approach to mammalian enamel from Africa, with a focus on sites that are important for understanding human evolution. The technique is being applied to diverse taxa (e.g. equids, suids, bovids, rhino, antelope) to build complementary geochronologies that improve the robustness of age assessments.

To better understand the processes of amino acid preservation, we are investigating taphonomic alteration of fossil enamel using an array of techniques including high resolution imaging. We are also exploiting the advances in microfluidic technology to develop a "lab-on-a-chip" approach for preparation of enamel samples, with a twofold aim: firstly, to reduce sample sizes from ~30 mg to ~ 1 mg; and secondly to ultimately enable IcPD dating to be undertaken outside specialist labs.

Direct cosmogenic nuclide isochron burial dating of early Acheulian stone tools at the T69 Complex (FLK West, Olduvai Bed II, Tanzania)

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Olduvai Gorge is one of the best-known paleoanthropological sites worldwide for the wealth of its Early Pleistocene paleontological-archeological record. This paper contributes to the ongoing effort to construct a solid geochronological framework for Olduvai archeological sequences by applying cosmogenic nuclide-isochron burial dating directly to stone artefacts. We apply the method to a new site named T69 Complex, located in the FLK West gully and positioned stratigraphically in Bed II. The chronology of Olduvai Bed II is not well constrained compared to underlying Bed I, due to fewer tephra layers suitable for K-Ar and Ar-Ar dating. This study applies a radiometric method that has never been attempted before at Olduvai Gorge. Cosmogenic nuclide-isochron burial dating is significant as it can be applied directly to stone tools, rather than indirectly estimating ages from surrounding sediments that are not always guaranteed to be the same age as the artefacts they contain. The method utilizes two cosmogenic isotopes (Be-10 and Al-26) measured in multiple samples collected from a stratigraphic horizon to determine a burial age. The approach is innovative by overcoming the uncertainty of conventional simple cosmogenic burial dating, e.g., the issue of post-depositional nuclide production. The stone tools selected for dating in this study were collected from the main archeological unit, T69L20. The dated artifacts are six cores and two hammerstones of quartzite. The resulting age in this study yields 1.48 ± 0.25 Ma for the Bed II sequence, which is consistent with previous dates from upper (~1.3 Ma) and lower bounding layers (~1.7 Ma). To our knowledge this is the first attempt to apply the cosmogenic nuclide-isochron burial dating directly to stone tools. The result is promising and opens up a new opportunity for future archeological studies. This Middle to Upper Bed II stratigraphic interval at Olduvai Gorge is a key period for our understanding of the disappearance of *Homo habilis* and the emergence of the Acheulian. This paper helps to more narrowly constrain the chronostratigraphic context to interpret assemblage variability during the onset of the Acheulian, at ~1.5 Ma in Olduvai Gorge.

Geochronology of Quaternary sediments at the Jeongokri archaeological site, South Korea

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The Palaeolithic site of Jeongokri, South Korea, is known for first discovering the so-called "Acheulian-like" handaxes in East Asia. The geology of this study area is composed of Precambrian gneiss, Jurassic granite, Quaternary unconsolidated gravel and sand layers, Quaternary basalt, Quaternary unconsolidated fluvial sediments and paleosols with decreasing age. The palaeolithic artefacts have been excavated from the uppermost paleosols in the Jeongokri area. In this study, direct dating of the artefact-bearing layers was attempted by applying OSL techniques, which showed great potential for use in the accurate determination of the timing of deposition. To extend the age range of OSL dating, a thermally transferred optically stimulated luminescence (TT-OSL) signal and single-grain K-feldspars using the post-Infrared Infrared stimulated luminescence (pIR IRSL) were also investigated. The Jeongok Basalts were directly analysed using the Ar-Ar method. ^{10}Be dating from the unconsolidated gravel and sand layers underlying the Jeongok Basalt were dated for burial age. These results of multiple absolute dating methods allow the development of chronologies of the Jeongokri archaeological sites and constrain the timing of the earliest hominin occupation in South Korea.

Finding and dating microlithic sites in the central Narmada Basin: a field memoir from an archaeologist's eye

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It has always been a dilemma for researchers working in the field of prehistoric or palaeolithic archaeology, especially in India, to find sites in a stratigraphical context and find a suitable dating method to establish geochronology. Majorly the sites are found in surface context. These archaeological logs on the landscape speak vastly of the palaeolithic occupations in India during the Quaternary period. Microliths are one of the small tool types abundantly found on the landscape all over India (apart from the Siwaliks and north-eastern India). Due to the lack of sites in a stratigraphical context, it has become nearly impossible to understand and comprehend the antiquity of microlithic sites in India. For the author's doctoral fieldwork (2015-2019), the central Narmada Basin was chosen to locate and document these microlithic bearing sites. Out of 225 microlithic occurrences, eighteen major sites were chosen for collections and out of these eighteen sites, six were shortlisted for OSL and sedimentology sample collections. Finding large sections in this region with microliths embedded in stratigraphy was daunting, and none were found. The spread of microliths was mainly restricted to the undisturbed areas of the pediment zone of the Vindhyans and Gondwanas. To select the sites for OSL dating, a few crucial factors were considered, i.e. the area should be least disturbed, artefact distribution and density, and artefact condition. Microliths were found freshly eroding from the 50 cm- 1-meter sediment accumulation, shaping into small mounds and the sample was collected from the middle of these sections. Sediment variation was seen at all the locations. After multiple visits to these shortlisted sites, OSL collection areas were selected, sections were correctly scraped, and the sample was collected following all the protocols. Aluminium and stainless steel tubes were used to acquire the sample. This paper discusses a preliminary attempt to date and establishes the geochronology of microlithic sites in the central Narmada Basin.

Tephrochronology in Scandinavia: precise dating of abrupt climate changes during the Last Glacial–Interglacial Transition

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Tephrochronology, meaning the usage of tephra deposits preserved in natural archives for dating and correlation purposes, has become a powerful and versatile chronological tool in palaeoclimate science as well as in other fields of study. Horizons of volcanic ashes (detected either as visible layers or as low-concentration "cryptotephras") can be found in sediments and ice at distal locations, far from their volcanic sources, and used as time markers that enable direct comparisons between study sites separated by vast distances. Tephra studies have been undertaken in Scandinavia for decades and recently presented results from Sweden and Norway provide insights into their application in the dating of abrupt climate changes during the Last Glacial–Interglacial Transition on various spatial scales.

Three well-known tephras have been identified at Körslättamossen in southernmost Sweden: the Icelandic Hässeldalen Tephra and Vedde Ash, and the German Laacher See Tephra (the first finding on Scandinavian mainland). This has enabled comparisons between palaeoclimatic reconstructions from this and other study sites in northern Europe, contributing to the interconnections of the European tephra framework and to the not-yet-settled debate of whether the Younger Dryas cold stage was a synchronous or a time-transgressive event in this region.

On the Fosen peninsula in central Norway, identifications of the Fosen Tephra and the Vedde Ash at a number of sites relating to the position of the Scandinavian Ice Sheet around the time of its Younger Dryas readvance have revealed errors in a previous chronology of the palaeoglacial events, acting as an example of tephrochronology's usefulness on the more local scales of landscape history and geomorphology.

Tephrochronology is not a perfect method; within the successes of the projects presented here lie also complications and issues that require further discussion and research efforts. The detection of tephra horizons can contribute significantly to age models, but only as long as the tephras can be confidently identified, and with methodological advances leading to new findings, the current state of tephrochronology is continuously becoming more complex.

Do anomalous fading limit the applicability of luminescence dating of Iron Age urns of Sivagalai, South India?

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Situating a particular archaeological event in history demand not only accurate but also precise ages estimated from radiometric dating methods. In a recent excavation at Sivagalai (8.6387° N, 77.9781°E) near the southern tip of India, rice grain found in an urn (A2 layer Urn 3) was radiocarbon (AMS) dated to be ca. 3100 years (3209 – 3000 cal BP). To test the applicability of the luminescence dating method, a total of 13 sub-samples were collected from five urns (A2 Urn 1, A2 Urn 3, L13 Urn 2, L13 Urn 5, and L13 Urn 8). Infra-red stimulated luminescence (IRSL) of polymineral fine-grain (4-11 mm) was used for equivalent dose (De) estimation using SAR protocol. As IRSL fades with time, the fading correction was done using three existing procedures. The effectual dose rate was computed from the three different sources of dose rate for age calculation. The ages obtained using polymineral IRSL were corrected using three different fading correction methods but all are inconsistent among them and with ^{14}C age suggesting a conspicuous failure of the fading correction procedures. This may be because these procedures are not able to correct for unusually larger fading rates (10.6 – 14.6 %/decade; 3-5 %/decade is the typical range). The XRD analyses suggested the presence of high temperature feldspar (sanidine) in the samples and that, possibly, can be associated with large fading rate.

In addition to conventional IRSL signal, unconventional signals (post IR IRSL, post violet IRSL and multiple elevated post IR IRSL) were also used for equivalent dose estimation. The result indicates that L13 URN 8 which may be younger than A2 Urn 3 for which AMS ^{14}C age is available, could be of ca. 2200 – 2500 years old. We also luminescence dated two samples in another premier laboratory and results are comparable. So, the question arises whether large fading rate limit the applicability of luminescence dating? Yes, if IRSL signal is used, but unconventional signals are promising to overcome this limitation. Experiments are underway and the results will be presented during the conference.

Session 135: Mammals biochronology and palaeoecology of the Euro-Mediterranean Quaternary

The Final Pliocene and Early Pleistocene faunal dispersals from east to Europe and correlation of the Villafranchian biochronology between eastern and western Europe

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The Villafranchian stage in the mammal fauna evolution in Eurasia (~ 3.4 Ma – 1.1/1 Ma) is associated with the beginning of the formation of the modern appearance of the fauna of today's Palaearctic. The time from the Mid-Piacenzian (~ 3.4-3.2) to the end of the Early Pleistocene was a time of particularly intense dispersal of species and of faunal exchange between Eurasia and Africa. Usually the dispersal is instantaneous from a geological point of view, but in some cases reaching W. Europe happens later. Of the three taxa that have become classic examples of bioevents associated with the beginning of the Pleistocene, *Equus*, Mammuthus and *Canis*, an example of a very rapid dispersal from the east is *Equus*. Its appearance in Eurasia is possibly already at the end of the Pliocene, but the first reliable dates are of the same age (2.6 Ma). The earliest *Canis* appearance seems to be related to *C. neschersensis*, found in one of the localities of Perrier with a probable age of 2.78 - 2.6 Ma (not in Vialette, as claimed, where the remains are from *Eucyon*), but the mass dispersal, the so called " Canis event" happens later: Slivnitsa, Bulgaria – Seneze, France (~ 2.1. Ma). An example of asynchronous entering is the mammoth, which appeared with *M. rumanus* in Eastern Europe earlier, at 3.2 Ma. Earliest *Vulpes* appearance in Europe is at Musselievo, Bulgaria (Middle-Late Piacenzian); *Panthera* ~ 2.5 Ma ago (Varshets, Bulgaria) and *Pachycrocuta* (Gerakarou, Greece), shortly after Slivnitsa time. The mass dispersal of bovids is particularly intense in MNQ18a (Slivnitsa). Rich Balkan localities such as Varshets, with an age between Roca-Neyra (2.6 Ma) and Saint-Vallier (at least 2.4 Ma) and Dafnero (2.4-2.3 Ma) mark the beginning of the Middle Villafrancian in the region. Slivnitsa (Bulgaria, ca. 2.1. Ma), shows a new cooling and closing of the Bosphorus and the time of potentially the earliest possible dispersal (Taman Peninsula) of *Homo* in Europe. Apollonia (Greece) correlate with the end of Pirro Unit. The probable appearance of *Panthera fossilis* is in Kunino (Bulgaria) - beginning (?) of the Galerian.

The field vole Microtus agrestis (Linnaeus 1761) from the Middle Pleistocene site of Schöningen 13 II (Germany)

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Schöningen is an important Palaeolithic locality in Central Europe, particularly famous for the wooden throwing spears that were found at the site Schöningen 13 II-4. The locality yielded also a huge collection of well-preserved small and large mammal remains from a late Middle Pleistocene sequence of deposits that forms the base of detailed palaeontological, palaeoecological and biochronological studies.

In this study, the first lower molars (m1) of the field vole *Microtus agrestis* recovered at the Schöningen 13 II sequence have been analysed from a morphological (n=102) and morphometric (n=50) point of view, focusing on changes in size (L) and on the relative elongation of the anterior part of the tooth (a/L). Our data show no significant changes in the a/L values (p=0.36), but a significant decrease in L (p=0.009) between layers Schö 13 II-3 and Schö 13 II-4.

Based on the ecological requirements observed in living populations, the decrease in size of *M. agrestis* through the sequence indicates a general decrease in humidity in the surrounding of the site, and in particular of the ground-water resources. A conclusion that is in agreement with the paleoenvironmental reconstruction inferred from the small mammal assemblages and with data from other environmental proxies.

The recurrent morphologies displayed by the m1s, and the stable values of the a/L index suggest the presence of a steady permanent population that adapted to the environmental changes rather than migration/dispersal of populations from/to nearby regions.

A comparison with other Middle Pleistocene sites from the Mediterranean area shows that the population of Schöningen differ from those of Italy or Spain. The values of a/L at Schöningen are higher than those from Mediterranean sites related to MIS 11-10, but lower than those related to MIS 9-6. The Schöningen population resembles the MIS 9-8 assemblages from Hungary. Future research will add more data from Central Europe and our on-going studies will allow to refine the biochronological position of the site Schöningen 13 II.

Palaeoecology and palaeoneurology of an enigmatic Early Pleistocene deer from Pirro Nord (Italian Peninsula).

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Medium-sized deer represent a good reference group for the Villafranchian fauna because of their abundance in Early Pleistocene deposits of Southern Europe. Their evolutionary history is still highly debated, as multiple classifications and systematic revisions have been proposed with specimens being ascribed to numerous fossil and modern genera such as *Pseudodama*, *Metacervoceros*, *Rusa*, *Axis*, *Dama*, or *Cervus*. While most studies focus on the taxonomy of the group, few have been performed on the evolution of cervids in relation to major Early Pleistocene climatic events such as the onset of the Quaternary glaciations. A remarkably rich collection of fossils belonging to this group of cervids has been unearthed from the Early Pleistocene site of Pirro Nord (Apricena, southeastern Italy). Here we analyse palaeoecological and palaeoneurological data of the Pirro Nord sample to investigate both habitat occupation and the evolutionary history of this group during the Early Pleistocene. To do so, we integrate dietary proxies (dental wear patterns and stable isotopes signal) with morphological data from a virtual endocast of a well-preserved male specimen, a largely unexplored research path in cervid palaeobiology studies. Moreover, palaeoneurological data may also provide clues to solve the systematics issue of this group. Dental mesowear results point to a long-term mixed diet for this taxon, while a leaning towards a grazing behaviour is suggested by dental microwear patterns. The range of the stable isotope $\delta^{13}C$ ratios implies that it foraged on abrasive water-stressed C3 vegetation in warm woodland and semi-open habitats, a result consistent with other palaeoenvironmental and palaeoclimatic reconstructions of Pirro Nord. Preliminary palaeoneurological data points to a closer affinity of the endocast morphology of this taxon to extant fallow deer *Dama dama* than to red deer *Cervus elaphus*. Our research represents a novel approach to the study of Early Pleistocene fossil deer palaeoecology that can be extended also to other groups to investigate their evolutionary history in relation to climate changes.

The Middle Pleistocene mammal fauna from the Megalopolis Basin (Peloponnese, Greece) and its importance for biostratigraphy and palaeoenvironment

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Megalopolis basin hosted during the late Early–Middle Pleistocene (~900–150 ka) a large and shallow lake, which resulted in a stratigraphic sequence composed mainly of lacustrine sediments intercalated by lignite seams. During the last decade (2012–2022) we conducted systematic and multidisciplinary field investigations in the basin, which led to the discovery of new sites with abundant archaeological/palaeontological material from stratified contexts, significantly enriching our knowledge of Pleistocene terrestrial ecosystems and hominin adaptations in the wider region. Here, we focus on three sites: Kyparissia-4, Marathousa-1 and Marathousa-2. We provide an updated overview of their mammalian fauna, and discuss the implications for biostratigraphy and palaeoenvironment.

The stratigraphically lowest of the three sites, Kyparissia-4, has yielded a diversified fauna rich in cervids, represented mainly by *Praemegaceros verticornis*. *Hippopotamus antiquus* is also quite abundant, including a partial skeleton. The coexistence of the voles *Microtus* (*Microtus*) and *Mimomys* spp. (medium- and large-sized species) at Kyparissia-4, indicates an early Middle Pleistocene age. Marathousa-1 (~500–400 ka, MIS 12; based on radiometric dating and magnetostratigraphy) stands out for its wealth in exceptionally well-preserved cultural, faunal and floral finds. Biostratigraphically correlated after the *Mimomys*/*Arvicola* transition, the vole assemblage is dominated by *Arvicola mosbachensis*. Alongside a diversified fauna, Marathousa-1 has yielded one *Hippopotamus* and two *Palaeoloxodon antiquus* (elephant) partial skeletons, the most complete fossil mandible of *Macaca sylvanus* (macaque), and the first record of "*Lutra*" *simplicidens* (otter) in Greece. The roughly contemporaneous Marathousa-2 has yielded mainly *Hippopotamus antiquus* fossils, some of which belong to a single individual. Anthropogenic modifications on elephant (Marathousa-1) and hippopotamus (Marathousa-2) bones provide evidence of megafauna exploitation and shed light on the subsistence behaviors of Pleistocene hominins.

Within the Early–Middle Pleistocene succession (middle Villafranchian–Galerian) of the Greek fossil record, the Galerian faunas of Kyparissia-4 and Marathousa-1, 2, mark the mammal reorganization close to the Early/Middle Pleistocene transition that took place in Europe. Finally, the presence of mammals generally indicative of temperate/milder conditions in different stratigraphic levels of the basin, including colder periods during glacial/stadial stages, points to their continuous presence in this southern region, which potentially comprised a refugium capable of retaining freshwater bodies throughout the year.

The Early Pleistocene large mammal succession of Greece: implications for pan-European biogeographic correlations

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Located at the eastern corner of Mediterranean Europe, Greece occupies a critical position for mammal dispersals to/from Europe, western Asia and Levant/Africa, and constitutes potential passageway towards western Europe. During the last decades numerous fieldwork campaigns in several sites (e.g., Dafnero, Sesklo, Vatera, Volakas, Libakos, Mygdonia Basin) by several palaeontological teams have greatly enriched the fossil record, and provided valuable taxonomic, biostratigraphic, palaeoenvironmental and taphonomic data.

Ongoing investigations by our team focus mainly in two regions: Dafnero (Western Macedonia), and Mygdonia Basin (Central Macedonia). Dafnero, dated to ~2.3 Ma, yielded a diversified middle Villafranchian fauna, rich in stenonoid horses, small- to medium-sized bovids, cervids and giraffids, and additionally includes the primate *Paradolichopithecus*. In Mygdonia Basin there are currently thirteen vertebrate sites, located in at least three stratigraphic horizons and correlated to different parts of the late Villafranchian–Epivillafranchian, broadly covering ~1 myr of faunal succession. The middle/late Villafranchian transition is well-captured at Gerakarou-1 (~2.0–1.8 Ma), the oldest Pleistocene site of the basin, where several taxa mark their last local appearance, while several others, like the hyaena *Pachycrocuta*, signify the beginning of a new biozone. Dated within the 1.8–1.5 Ma interval, Tsiotra Vryssi, the Krimni sites and Kalamoto-2, are characterized by a combination of typical late Villafranchian components, and more "archaic" elements, while they document the co-occurrence of the bovines *Leptobos* and *Bison*. The gradual faunal "modernization" terminates in the youngest site of the basin, Apollonia-1 (~1.3–1.1 Ma), close to the late Villafranchian/Epivillafranchian boundary, where the assemblage is dominated by large-sized horses and large-sized bovids and cervids, accompanied by a diversified carnivoran guild.

Based on previous studies and new data we provide the updated local Early Pleistocene mammal succession by means of Faunal Units and discuss key taxa in both regional and pan-European frame. Using available local chronological markers, and biochronological evidence, we time-calibrate the local faunal scale and correlate it with well-dated faunas of western Europe. The results form the basis for discussion of already set turnovers, dispersal and extinction/immigration events, and showcase the importance of the local record for the investigation of the European terrestrial ecosystems.

An updated review on the Plio-Pleistocene large mammal assemblages from the Iberian Peninsula

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At the dawn of the new century, several new Pliocene and Pleistocene sites have been discovered, and subsequently excavated, in the Iberian Peninsula during the XXI Century. The plethora of information obtained from these new field surveys, combined with the new taphonomic and paleoecological research performed on old collections during the last two decades, improved substantially our knowledge on the Iberian Plio-Pleistocene ecosystems.
Especially noteworthy are the data obtained from the new field surveys on the Ruscinian locality of Baza-1 (Baza basin, Andalusia) and Camp dels Ninots (Catalonia). Furthermore, new discoveries were made on Late Villafranchian and Epivillafranchian localities of the Peninsula (e.g. Vallparadís Section in the Vallès basin, Catalonia and the Orce sites in the Baza basin), including a continuous pre-Jaramillo to Jaramillo succession (Quibas complex, in Murcia). Finally, new prospections and surveys conducted on central Iberia and Pyrenean sites of Middle to Late Pleistocene have shed new light into the dynamics of glacial stages in Western Europe after the Early-Middle Pleistocene transition (EMPT).
At the end of Pliocene, the onset of new climate dynamics, characterized by Glacial-Interglacial phases, reshaped the structure of the previous ecosystems and, subsequentially, the faunal associations of Western Europe. A successive climatic transition, the EMPT, furtherly extreme the delicate conditions that allowed the persistence of tropical associated taxa, triggering the transitions toward more modern faunas.
The new data emerged by the study of the above-mentioned localities provide us a new glimpse on the Iberian environments and its inhabitants before and after these transitions. Here we present the latest results and an updated review of the Iberian Plio-Pleistocene assemblages with special emphasis on the climatic changes and the related biogeographical associated consequences.

Dietary traits of Haploidoceros mediterraneus, a biochronological marker of the transition from the Middle to the Late Pleistocene in southwestern Europe

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Haploidoceros mediterraneus is a peculiar medium-sized deer with scarce occurrence. It is geographically limited to an area at the southwest of Europe. *H. mediterraneus* is distinguished from other similar-sized deer on the basis of the antler shape. The species has been identified in five sites in southwestern Europe. In southern France, it has been recovered in two Late Middle Pleistocene sites (MIS 9–7), Lunel-Viel (Hérault) and Igue des Rameaux (Tarn-et-Garonne). In the Iberian Peninsula it has been documented at Cova del Rinoceront (Barcelona) and PRERESA (Madrid), providing a longer time span for the genera at least until MIS 5 (early Upper Pleistocene). The absence of *H. mediterraneus* at younger sites suggests that extinction could be occurred at the beginning of the Last Glacial period, at least in the Iberian region, and make this species a biochronological marker of the late Middle to early Upper Pleistocene. The aim of this presentation is to analyse its diet which is still poorly known and to highlight the palaeoecological significance of this species. For this purpose, we performed tooth mesowear and microwear analyses to reconstruct the dietary traits and habitat of *H. mediterraneus* from Lunel-Viel, Igue des Rameaux, Cova del Rinoceront and PRERESA. All the populations of *H. mediterraneus* show browsing or browse-dominated mixed feeding dietary traits. In comparison to other cervids from the same localities, when they co-occur, the dietary traits show different patterns. At Igue des Rameaux amont it overlaps with the red deer while at Lunel Viel it has lower abrasive diets than the red deer (caves I and IV) and the megaloceros (cave I). It also fits within the dietary range of the extant red deer and fallow deer. The analysis of the dietary traits indicates that *H. mediterraneus* is a rather eurytopic species in comparison to *C. elaphus*. It that was living in mixed wooded vegetation under temperate environmental conditions. Our results indicate that besides being a good biochronological indicator, *H. mediterraneus* is also a significant palaeoecological marker for the Middle and Late Pleistocene of southwestern Europe.

An updated review of the Quaternary hippopotamus fossil record from Iberian Peninsula

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Several large mammal taxa with African affinities, including Hippopotamidae, have extended their geographical range into Europe several times during the Quaternary. A first entry of *Hippopotamus* into European continent via the Levant is generally accepted, with their oldest recorded occurrences in Turkey, Greece and Italy (ca. 2.1-1.8 Ma). Less clear is the purported second migration of this group, with earliest records around 0.5 Ma. To clarify this biogeographical and dispersal pattern, a detailed revision of the fossil record of *Hippopotamus* in Europe, Africa and Levantine area is therefore necessary. In this work, we review the fossil record of *Hippopotamus* from the Iberian Peninsula, continuing with the inertia of research begun in recent years for areas such as Italy and Greece. The most widely shared hypothesis considers the presence of two species of the genus *Hippopotamus* in the Iberian record. *H. antiquus* has potential records in the Peninsula starting from 1.7 Ma, at the Mencal-9 (Granada) site, until the mid-Middle Pleistocene, when hippopotamus specimens begin to be attributed to *H. amphibius*. The attribution of the Early Pleistocene specimens to *H. antiquus* is well supported, with the discovery of partial or complete skulls at sites such as Vallparadis Section (Barcelona), Incarcal Complex (Girona), Barranc de la Boella (Tarragona), Bòvila Ordis (Girona) and Barranco León (Granada), or complete limb bones such as Algoz (Algarve). On the other hand, very few Middle Pleistocene specimens can be clear taxonomically determined to establish the precise timing of the specific turnover. Only the material from the site of Mealhada (Aveiro) have been studied paleontologically, defending the presence of *H. amphibius* at the end of the Middle Pleistocene. However, these specimens are documented by a phalanx and a cuboid, that are, objectively, difficult to identify at specific level. Accepting the presence of *H. amphibius* in this chronology, the LOD of this species in the Iberian Peninsula would be referred to MIS 4, in the Toll cave (Barcelona). It is worth mentioning the discovery of two sites, Barranco León and Bolomor Cave (Valencia), which represent one of the few confirmed European contexts with evidence of human exploitation of hippopotamuses.

The Epivillafranchian in European biochronology: marker taxa, boundaries, and localities

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Biochronology is one of the most used and powerful approaches to relate biological events to the geological time scale in the terrestrial realm. In Europe, the period that embraces the last ca. 3.3 Ma is traditionally defined by the succession of three European Land Mammal Ages (ELMAs) based on large mammals, defined by Italian palaeontologists and today widely used on a continental scale. These ELMAs are the Villafranchian (ranging from the late Pliocene to most of the Early Pleistocene), Galerian (from the late Early Pleistocene to the mid Middle Pleistocene), and Aurelian (spanning the last ca. 0.4 Ma). These biochrons cover a crucial phase in European palaeoenvironmental and palaeoclimatic evolution, which includes the establishment of Quaternary glacial-interglacial cycles.

About 1.2 Ma, the obliquity-forced 41 ka glacial rhythm characteristic of the Villafranchian started to change, with a progressive increase in the amplitude of climatic oscillations and the establishment of strong asymmetry in global ice volume cycles. The shift towards a 100 ka cyclicity was followed by the first major build-up of global ice during MIS 24–22 (ca. 0.9 Ma). These events - grouped within the so-called Early–Middle Pleistocene Transition (EMPT) - led to major environmental changes and faunal turnovers in Europe, and ultimately triggered the extinction of Villafranchian taxa which were unable to adapt to the harshening of environmental conditions and to the dispersal of newcomers from Asia and Africa (including *Homo*). In European biochronology, this transitional period has been recognized under the name of Epivillafranchian. This biochron, spanning from ca. 1.2 to 0.8 Ma, is a pivotal period for understanding the processes that shaped European modern mammal faunas.

Here we present a comprehensive reappraisal of the Epivillafranchian concept, revising its marker taxa and chronological boundaries by means of the analysis of some of the most important localities. Given the significant amount of data collected in the last years that support the existence of “transitional” faunas in Europe between the Villafranchian and Galerian, in agreement with other authors we strongly support the use of the Epivillafranchian as a formal biochron in the ELMA system.

The Epivillafranchian carnivoran guild from the Vallparadís Section and the Early-Middle Pleistocene Transition

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Since the Late Pliocene, the intensification of the glacial dynamics in the Northern hemisphere induced changes in the European ecosystems. The progressive shift from wooded areas with tropical affinities to mixed forest, forested-steppes, and savanna-like environments favored the dispersion of large ambush-pursuit predators (e.g., *Homotherium*, *Megantereon*, *Xenocyon*) into Europe.

At the latest Early Pleistocene, the progressive increase in the amplitude of climatic oscillations started, which induced the onset of a strong asymmetry in the global ice volume cycles. This interval is named "Early-Middle Pleistocene Transition" (ca. 1.2-0.4 Ma) or EMPT. The time range includes the so-called "0.9 Ma event" when the first relevant build-up of global ice occurred.

The available European fossiliferous sites with multiple stratigraphic horizons spanning the entire EMPT interval are overall scarce. The Vallparadis Section (ca. 1.2-0.6 Ma) is among the few localities that recorded this period. Through the section that comprises the late Early Pleistocene period, the Carnivora guild includes long-persisting taxa such as *Homotherium crenatidens*, *Megantereon* sp., *Panthera gombaszoegensis*, *Puma pardoides*, *Lynx pardinus*, *Pachycrocuta brevirostris*, *Canis (Xenocyon) lycaonoides*, *Canis mosbachensis*, *Vulpes alopecoides*, and *Meles meles*. Most of these taxa persist in the section until MIS21 (ca. 0.85 Ma) and survive the '0.9 Ma Event'. In addition to that, other newcomers, such as *Panthera fossilis* and *Ursus deningeri,* appear in the section around MIS31 (1.05 Ma).

The progressive cooling trend of the EMPT favored the spreading of open habitats in the whole of Mediterranean Europe, and with it, the dispersal of these new carnivores, the reduction of diversity, and the interspecific competition. Here we present a review of the Vallparadís Section Carnivora guild, focusing on the co-occurrence of the remnants of Early Pleistocene guilds and the first Middle Pleistocene groups entering Europe during the Epivillafranchian.

The thorny question of the absence of suids from Europe during the Late Villafranchian

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According to an influential hypothesis, suids would have been absent from Europe during the post-Olduvai to pre-Jaramillo late Early Pleistocene (c. 1.8-1.2 Ma). Arguments enumerated in favor of this “suid gap” are the lack of suid remains from extensively sampled fossil localities of this age and the r-selected reproductive strategy of suids, which would translate in a high representation of their remains in the fossil record. However, while the reproductive potential of suids might explain their evolutionary success and current dynamics of increase of wild boar populations, there is apparently no direct relationship between reproductive strategy and preservation rate of a taxon in the fossil record. In fact, latest Early Pleistocene (Epivillafranchian) suids are often documented by fewer remains than many other artiodactyls of similar size. Moreover, while it is undeniable that suid fossils have not been recovered from several European localities dated between c. 1.8 and 1.2 Ma, there are some remains that could fill this apparent gap. The case of suids underlines an important caveat often neglected in inferring faunal dynamics of the late Early Pleistocene of western Europe —including the dispersal of hominins— i.e., the unequal geographic distribution of most extensively investigated paleontological sites of the c. 1.8-1.2 Ma age (mainly located in the Iberian and Italian Peninsulas), and hence the resulting probable bias for biochronological correlations. The dependency from biochronology is salient for correlating localities of the c. 1.8-1.2 Ma period, given the paucity (or low resolution) of available radiometric estimates and of paleomagnetic reversals detectable in continental deposits. In other words, it is not possible to rule out that Late Villafranchian suid populations survived at low demographic densities or in scarcely sampled areas (e.g., France and Germany), and the same might be true for other species.

Time matters: testing for ecological niche changes in Late Quaternary European ungulates

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The last 50 thousand years represent a very informative period for the study of paleoecology. From a climatic point of view, they are characterized by large fluctuations which greatly impacted the environment. From a methodological perspective, they are covered by the radiocarbon dating method that allows precise chronological attribution of the archaeological record, and association with palaeoclimate. Finally, the recent development of nearly-continuous palaeoclimatic data series over the last tens of thousands of years provides the appropriate context to investigate species responses to climatic change over this time scale.
We developed a novel modelling framework to reconstruct the paleoecological dynamics of large animal species, and we applied it to four generalist European ungulates that survived the Pleistocene-Holocene transition: horse, aurochs, red deer, and wild boar.
We not only reconstructed their distribution through time, but we also tested if their realized niche changed in response to the climatic changes observed in the region between the last part of the Pleistocene and the Early Holocene.
We could show that all four animals changed their niche with species-specific responses to climate fluctuations, despite being generalist and showing similar wide distributions through time. We also suggest the fact that species with long generation times can change their niche over time frames in the order thousands of years cautions against assumptions of niche stability when studying Late Pleistocene paleoecology.

The Late Pleistocene spotted hyena (Crocuta crocuta) from San Teodoro Cave (Sicily, Italy) and implications for the evolutionary history of Mediterranean Quaternary Hyaenidae.

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In 1859, while Darwin was publishing his monumental work on the origin of species, the cave of San Teodoro was discovered at Acquedolci, a small town along the north-eastern coast of Sicily, in the province of Messina. The richness of Late Pleistocene faunal remains and Upper Palaeolithic human burials and artefacts, has made this locality a key site to explore human and animal diversity and distribution on Mediterranean islands. Taking into account the Late Pleistocene fossil record recovered from San Teodoro Cave, coprolites and bones of *Crocuta* stand out for their abundance. These remains suggest a prolonged period of occupation of the cave by hyenas, a hypothesis supported by the occurrence of adults and cubs, whose bones show, in some instances, clear evidence of bitemarks produced by other hyenas. In the last years, the San Teodoro Cave was the subject of several taphonomic studies, indicating this site as one of the best preserved hyena dens of the Late Pleistocene of Europe. Despite this, a formal systematic description of the hyena osteological remains is still missing.

In this contribution, we provide a brief summary of the first comprehensive study of cranial and postcranial bones of the Late Pleistocene *Crocuta* from San Teodoro Cave, and its implications for taxonomy and evolutionary history of Mediterranean Quaternary hyenas. The study includes biometric and morphological analyses carried out by making comparisons with extant and fossil hyenas, and a CT-based description of the virtual casts of both brain and paranasal sinuses. Due to the large number of damaged epiphyses, biometric analyses were mainly performed of craniodental material.

Attractiveness of the Denizli Basin for humans and animals during the Early Pleistocene (1.6-1.2 Ma). A pathway to Europe through Anatolia?

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At the crossroads between Africa, Asia and Europe, Turkey occupies an important place to follow animal and human dispersions through time. However, Pleistocene sites with macrofauna are relatively rare in Turkey. Consequently, the upper travertine of the Denizli Basin, whose delivered bones of large mammals as well as other indicators of biodiversity (voles, crabs, leaves, ostracods…) and a fragmentary *Homo erectus* skull, constitutes a key-site to track the different migratory paths. Multidisciplinary work including biochronology, dating by cosmogenic nuclides, paleomagnetism and combined ESR/uranium-series, constrains the fossiliferous deposit between 1.6 and 1.2 Ma.
Thus far, the faunal list consists of the following taxa: *Archidiskodon meridionalis meridionalis*, *Stephanorhinus* cf. *etruscus*, *Equus* cf. *apolloniensis*, *E.* cf. *altidens*/*E.* cf. *mygdoniensis*, *Metacervoceros rhenanus*, *Arvernoceros* sp., *Cervalces* (*Libralces*) ex gr. *minor-gallicus*, *Gazella* sp., *Palaeotragus* sp., Bovinae gen. indet. This fauna is characterized by the mixture of ("archaic") Villafranchian components (cervids, *Palaeotragus*, *Gazella*) and "modern" late Villafranchian newcomers as the advanced equid *E. apolloniensis*. At the regional scale, comparisons are limited. The association is older than the central Anatolian record of Dursunlu (0,9 Ma) which includes *Mammuthus trogontherii* and a caballoid horse. The neighbor localities of Yassigüme (Burdur Basin) share Villafranchian typic taxa as *Leptobos* cf. *etruscus* and *Gazellospira* together with more primitive stenonid horse. In a larger window, the Denizli's fauna resembles those from the late Villafranchian of Southern/Eastern Europe, and, to some extent, from Western Asia. Affinities are found with eastern Mediterranean fauna from the Early Pleistocene of Mygdonia basin (Macedonia, Greece). The association from Denizli can be correlated with early Late Villafranchian Psekups Faunal Complex from Ciscaucasia. At the same time, the Kocabaş skull has been shown to be closer to African fossils (1.8-1 Ma) than to *Homo erectus* from Dmanisi and Asia and a role in the settlement of Western Europe has been suggested.

From the palaeoenvironmental perspective, the Denizli's fauna can be confronted to the exceptional pollen archive from the Acigöl Lake located a few tens of kilometers. Most of Denizli herbivores are thermophilic species occupying different biotopes around the basin, which may have represented an attractive watering place with ample vegetation.

The faunal response to EMPT in Central Europe

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Faunal dynamics associated with the Early Middle Pleistocene Transition (EMPT), an essential turning point of the Late Cenozoic history, was investigated using a rich fossil record obtained from a series of complex sedimentary sequences in the Czech Republic. Cross correlation of particular sedimentary series supported by the magnetostratigraphic and morphostratigraphic references enabled to date most of the records in terms of climatostratigraphic units and reconstruct putative faunal rearrangements during the period from MIS 22(23) to MIS 14.

In total we analyzed 64 community samples of small ground mammals (MNI>15) recognizing 45 phenotypically distinct taxa. Total abundance of the set was 13995 (MNI), mean sample abundance was 218.7 (MNI). In all, the community structure both in terms of species composition and dominance structure was in general quite similar. The community core was invariantly formed by ten euconstant species, each of which apperared in more than 50% of samples. Yet, particularly in the earlier section of the covered period (MIS 22-17), the community structure was considerably enriched samples by regular appearance of diverse recedent and subrecedent elements including the taxa representing index species of EMPT period (*Macroneomys brachygnathus, Petauria voigtstedtensis, Dicrostonyx simplicior, Lagurus transiens, Spermophilus dietrichi*). LAD *Beremendia fissidens* and FAD *Sorex minutissimus, Lemmus/Myopus, Pteromys volans, Neomys newtoni* or *Sicista subtilis* in that time are worth of mentioning.

In general, the faunal history of EMPT can be characterized by (i) establishing the axial community structure (perhaps during MIS 22 or earlier), (ii) enriching community structure by appearance of novel recedent elements including alien distant immigrants during subsequent stages MIS 21-17, (iii) reduction of diversity during the glacial stages terminating Q2 stage of Late Biharian (MIS 16) and subsequent climatic cycles forcing the phenotype rearrangements of resident taxa (e.g. *Mimomys savini* to *Arvicola*, *Lasiopodomys gregaloides* to *anglicus* etc.).

Correlations of the studied sites with a morphostratigraphic sequence of river terraces suggest an abrupt uplift of the region during MIS 22-17 responding obviously to global tectonic processes promoting onset of the EMPT and related environmental rearrangements.

Session 137: Geological and climate forcings on human groups / ancient societies, and their feedbacks

Environmental Risks and Societies: From hunter-gatherers to the industrial civilization

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Environmental risks fall into two categories: natural risks and risks induced by the interaction between human action and environmental dynamics. Natural hazards, which only become risks insofar as their consequences affect human societies, are unchangeable and can be listed as follows: meteorite impacts, volcanic eruptions, earthquakes, tsunamis, mass movements, climate change and extreme weather events (hurricanes, storms, droughts, bushfires…), epidemics. Depending on the areas of civilization and the historical periods, those risks were more or less understood and taken into account. The very slow progression of human groups on the surface of the planet – estimated at 5 km per generation for the Neolithic period, for example – has facilitated the acquisition of the pragmatic skills necessary for survival, but it was not until the contemporary era that proper concepts were available to explain those phenomena. Our civilization is the first to have the capacity to reconstitute past hazards, to determine risk zones and to be able to at least partially model future developments. The risks induced by the interactions between human action and environmental dynamics have continued to increase as the population grew and the ecumene was conquered. The hunter-gatherers and farmers of the Neolithic period coped with the risk of famine or starvation in different ways, while the cohabitation between man and domesticated animals, the emergence of cities and commercial exchanges favored the spread of new diseases and the risk of epidemics. Over the 300,000 years that have elapsed since the appearance of Homo Sapiens, human societies have proved to be resilient in the long term and on a global scale, when faced with both cycles of climatic fluctuations and variations in sea level and disasters triggered by human action. Paradoxically enough, the more developed societies are, the more complex their functioning is and the higher the cost of their reconstruction or reorganization is. On a planet where no more space can be considered as natural, will we succeed together in finding the necessary compromise between the protection of biodiversity and societal balance which includes satisfying the needs of the populations?
Keywords: Environmental risks, Societies, Anthropocene, Geoarchaeology

Neanderthals' technological change and environmental adaptation at the onset of MIS 4 at the edge of the Adriatic-Po region

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Along the northern edge of the Adriatic-Po region plain and in the Prealpine belt of Italy, the climatic worsening related to the stadial phase of Marine Isotopic Stage (MIS) 4 is marked by the expansion of Alpine ice coverage and widespread loess accumulation, while the pollen cores record a mosaic of boreal forest and steppe with the occasional presence of warm-temperate taxa. Consistently, we report substantial changes in the cultural complexes and technological behaviours of Neanderthal groups which populated the Great Adriatic-Po Region (GAPR). While Levallois Mousterian is by far the most common lithic techno-complex up to MIS 5, in MIS 4 there is an increase in technological diversification associated with higher versatility and duration of the produced blanks. These are well exemplified by the Quina and demi-Quina scraper, a long-live, multi-purpose retouched tool which was considered the pivot of the productive ramifications typical of these contexts. In support to these assumptions, we present the case studies of De Nadale cave, a single-layered Mousterian site located in the Berici hills, and of the small lithic assemblage from Fumane cave BR6 unit, a layer framed in a well-known and representative sequence for the Late Middle Palaeolithic located in the Lessini Mountains. These lithic assemblages show the adoption of diversified strategies having much in common with the contemporary Western European Quina classic sites, however distinguishing from the latter for an application of more diverse knapping methods and techniques aimed at producing both thick, portable Quinoid blanks, and ready-to-use thin flakes and bladelets. Contextual information available from paleoenvironmental, zooarchaeological, petroarchaeological and functional analysis concur to correlate this technical behaviour to a planned strategy in response to a seasonal and organized mobility and a moderate rarefaction of resources. In constrained ecological contexts, Quina production could represent an optimal adaptation in order to maximize the effectiveness of lithic tool-set in respect to the demanded functional needs. The recorded differences could reflect local adaptations related to the emergence and spread of Quina concept in the GAPR during the last glacial cycle.

Birth, life and death of a lithic technological tradition: exploring the influence of climate on the apparition, generalization and disappearance of the Rayssian during the Middle and Recent Gravettian in France (32–26.5 ka calBP)

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A frequent hypothesis in archaeology links material cultures variability to their environmental contexts. In this study, we reflect on the cultural and environmental factors that influence the appearance, generalization, and disappearance of the Middle Gravettian Rayssian lithic tradition. It is defined as a unique method used to produce hunting weapon implements and that differs conceptually from those used before (Noaillian) and after (Recent Gravettian) it. The set-up and termination of this tradition are chronologically associated with periods of high climatic instability, such as the cold and abrupt Heinrich event 3 for its appearance or the GI 4 climate amelioration for its disappearance. However, the reality of a causal link between technological and ecological variability needs to be evaluated via a quantitative and interdisciplinary approach aimed at better integrating archaeological and paleoenvironmental data.

We evaluate the extent to which this technological trajectory was influenced by the exploitation of different environmental conditions using the approach termed eco-cultural niche modeling. To do so, we chose relevant climatic variables to represent the environment and constructed a critical inventory of sites that can be assigned to the Noaillian, the Rayssian, and the Recent Gravettian. Their eco-cultural niches were then modeled, statistically evaluated and compared.
Our results indicate that technological changes and shifts in sites' geographic distribution are associated with eco-cultural niche dynamics in both environmental and geographic dimensions. Building on these results, we propose an interpretive scenario that highlights the role of environmental factors as well as their interaction with social factors (e.g., subsistence strategies, territorial organization, transmission biases) in the delineation of mechanisms involved in the Rayssian cultural trajectory.

Tracing human-environment interactions using high-resolution palaeoclimatic shell proxies from Franchthi

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In this presentation we will demonstrate how the archaeological shell record can provide valuable insights on human-environment interactions and the palaeoclimate on a human-time scale. Our method combines effectively sclerochronology with spectroscopy and chemical isotope analyses in order to extract high-resolution climatic data. Our aim is to contribute to the reconstruction of the climate of the past and its impact on past communities during the Early Holocene. For this purpose, we employ *Patella* shells as it has been shown that they preserve in their elemental composition site-specific high-resolution information on past climatic and seasonal conditions. Limpet shells from Franchthi, a coastal prehistoric site in southern Greece, have been chosen for analysis as it constitutes a well-investigated site in the Eastern Mediterranean. By applying our methods on the palaeoenvironmental shell archive while considering other palaeoenvironmental proxies, we intend to reconstruct climatic variability on a local, site-specific, scale and determine to what extent human activities were influenced by long- or short-term trends of the climate. Furthermore, our method can approach temporal sub-annual scales that would have been perceived by the inhabitants of the site. Overall, this work intends to examine the ways in which the prehistoric inhabitants of the site were affected in terms of subsistence and social practices by potential fluctuations in the local paleoenvironmental conditions through the archaeomalacological record as well as inherent high-resolution paleoenvironmental datasets.

Seasonality and possible forcings on millennial-to-orbital scale hydroclimatic changes in southwest Mexico and central Mesoamerica during the latest Pleistocene, Holocene and last 2 ka

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Speleothems from central Mesoamerica in southwest Mexico with growth-hiatus have documented the influences of climate change and the dynamics of paleo-monsoon over the late Pleistocene and Holocene. The results of this study provide new data and a continuous register of palaeohydrological and palaeoecological conditions by reconstructing the responses of allochthonous and autochthonous components of a lacustrine ecosystem at Coatetelco over the last 18 cal ka that is presently an important source of surface water for agriculture in the region, and possibly played a vital role in the flourishing and demise of Xochicalca culture over the last 2 ka. Sediments deposited in this perennial lake (precipitation: ca.1085 mm/a) with its wettest condition in autumn and a dominantly volcaniclastic watershed, provided an opportunity to evaluate the hydroclimatic changes in millennial to orbital scales over the latest Pleistocene (deglaciation), the Holocene and last 2 ka with respect to different atmospheric and oceanic forcings as well as varying insolation. Stratigraphic changes in Ti, $CaCO_3$, $\delta^{18}O_{carb}$ and $\delta^{13}C_{carb}$ in inorganic fractions and TOC, $\delta^{13}C_{org}$ and C/N in the organic fractions suggested wetter conditions during the Bølling–Allerød (B/A) interstadial, early to middle Holocene (EMH, ~11.5-6 cal ka BP) and the Pre-Classic Period of Mesoamerican chronology, contemporary to the Escarpa phase of the Xochicalca culture. In the orbital-scale, the wetter phases of B/A and EMH were contemporaries with intervals of high spring and summer insolation. This possibly reflects changes in seasonality of the wet conditions in the region since the deglaciation. In the millennial-scale, however, the wet phases were forced by the latitudinal shifts in mean position of the ITCZ. Sediments of arid 6–4.2 cal ka BP and YD showed geochemical similarity with sediments of the Post-Classic drought, coeval with abandonment at Xochicalco. Seasonal insolation at orbital scales modulated southerly ITCZ might have forced the first two droughts and ENSO possibly forced the drought that caused cultural demise at Xochicalco.

Roles of different climatic factors on human population change in Eurasia between the Last Glacial Maximum and the early Holocene

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Archaeological records document a significant expansion of populations from the Last Glacial Maximum (LGM, ~23-19 ka) to the early Holocene (EH, ~9 ka) in Eurasia, which is often attributed to the influence of orbital-scale climate changes. Yet, information remains limited concerning the climatic factor(s) which were responsible for conditioning demographic patterns. Here we present results from an improved Minimalist Terrestrial Resource Model (MTRM), forced by a transient climate simulation from the LGM to the EH. Simulated potential hunter-gatherer population densities and spatial distributions across Eurasia are supported by observed archaeological sites in Europe and China. In the low latitudes, potential population size change was predominantly controlled by precipitation and its strong influence on plant and animal resources. In the middle-high latitudes, temperature was the dominant driver in influencing potential population size change and animal resource availability. Alternate regional responses of potential populations to climate change across Eurasia - owing to variations in available food resources between the LGM and EH - have broader implications on climate-human population interactions, including a better understanding human dispersal during the Late Pleistocene.

Changes in limiting factors of forager population dynamics in Europe between the Last Glacial Maximum and 8ka BP

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Population dynamics in humans set a framework for genetic, cultural, and linguistic evolution. Multiple studies have shown coupling between demographic changes and shifts in environmental variables linked to productivity, eco-physiological limits, and seasonality. However, most of these statistical models assume constant effects on environmental variables and human population density through time. Here, we evaluate this assumption using a phenomenological statistical approach to evaluate changes in the limiting environmental factors – a factor or variable that restricts growth, abundance, or distribution of a population in an ecosystem – on population density from 21k to 8k years before present. Based on a global ethnographic hunter-gatherer dataset, we built a series of Generalized Additive Models (GAMs) to describe changes in human population density as a univariate function of temperature and precipitation variables related to available energy, seasonality, and productivity. These univariate GAM models were projected over Europe for the envaulted period using centennial average-conditions of each predictor derived from a transient downscaled climatic simulation (SynTraCE-21). Whichever variable at a site × time-step predicts the lowest population density is considered the limiting factor. Between the Last-Glacial Maximum (LGM) and the start of the Holocene, the most dominant limiting variables across Europe show district patterns linked to key climatic change. At a continental scale, energy availability was the main factor limiting population density between the LGM and the onset of the Younger Dryas (YD). During and after the YD, and until the 8kaBP, seasonal water availability was the main limiting factor to population density. The regional disaggregation of patterns in limiting factors shows strong differences between Fennoscandia, Southern, Central, and Eastern Europe. Changes within and across these regions are linked to the Bølling-Allerød interstadial and the start/end of the YD. Our results show how the main limiting factors for forager population density change over time and space, setting the dynamic stage for genetic, cultural, and linguistic evolution.

An abrupt change in vegetation and pollen production during the Late Boreal: implications for hunter-gatherer communities in northern Belgium during the 9.3 ka event

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Hunter-gatherer societies rely primarily on their environment for vital resources such as fresh water, edible plants, game, fish and wood. Environmental changes likely have had a large impact on Mesolithic societies and may have led to adaptations and innovations. Middle Mesolithic innovations along the southern North Sea basin (Belgium, southern Netherlands, northern France) include transformations in lithic technology regarding hunting gear and the increased use of exotic raw materials. Moreover, there are indications of a regional decrease in site densities, as well as changes in burial practices.

Early Holocene vegetation changes in northwestern Europe are well-documented and reflect the colonization and spread of various trees and herbaceous plants as climate changed after the last ice age. The stable oxygen isotopic records of the Greenland ice sheet reveal several small-scaled climatic changes, such as the cooling events at 8.2 and 9.3 ka. Relatively short-lived events may often remain unnoticed in vegetation reconstructions due to the sampling resolution, and in the case of the 9.3 ka event, the limited availability of organic-rich archives that span the Boreal. However, recently peat comprising the entire Boreal was found in the Grote Nete Valley in the Province of Antwerp, Belgium. A high-resolution pollen and macrofossil analysis of this well-AMS-dated peat record allowed a detailed reconstruction of the Boreal vegetation.

Pollen assemblages indicate that birch-pine woodland in the late Preboreal shifted to pine-dominated forests in the Boreal. After the initial expansion of hazel, followed by oak and elm from the early Boreal onward, a prominent and abrupt reduction of the pollen concentration, by up to 95% over several spectra, is observed during the second half of the Boreal. This sharp decline affects all plants and coincides with a decrease in pollen percentages of thermophilous trees and an increase of the cold-tolerant pine. The age model suggests this shift in pollen concentration and vegetation composition likely reflects a climatic cooling at 9.3 ka.

The implications of this Boreal vegetation change for Middle Mesolithic hunter-gatherer communities will be discussed in the light of resource stress in the gradually drowning landscape of the North Sea basin.

Holocene climate changes and human occupation in northern Europe – divergent developments on the prehistoric coastal and inland settlements

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Spatially synchronous population fluctuations are widespread phenomena in nature. These fluctuations are detected also among disjunct populations of Holocene coastal hunter-gatherers in northern Europe. The synchrony appears to be a result of similar responses to positively correlated environmental variability, thus following the so-called Moran effect. Here, we focus on a northernmost part of Europe and compare population and climate trajectories between coastal Arctic Ocean and inland areas of eastern Fennoscandia.

We reconstruct human population dynamics using summed probability distributions of c. 3000 radiocarbon dates from archaeological contexts to inquire the spatiotemporal patterns in the human population development in this vast geographical area. In addition, we use quantitative pollen-based temperature reconstructions across northern Fennoscandia as well as climate model simulations to assess the climate dynamics and possible correlation between climate and human population fluctuations.

We find that coast and inland show synchronous population fluctuations. However, these fluctuations are negatively correlated between coastal and inland areas. We align population reconstruction with the temperature reconstructions and climate model data to see if the opposing patterns of population trajectories could be explained by differences in climate trajectories between coastal and inland areas or if similar climate trajectories had opposing effects on the suitability of coast and inland areas for hunter-gatherer populations of northern Europe.

Furthermore, we assess the signals of cold Holocene abrupt climate events, associated with cold temperatures in northern-hemisphere climate proxy data, and discuss which of these centennial climatic disturbances correlate with the archaeological proxies and what was their possible effect on coastal and inland population development and divergence.

The 4.2 ka event in the Himalaya in light of vegetation and precipitation change and its influence on the Harappan culture in the Indian subcontinent

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For many human cultures of this time, the drought event of 4.2 ka was one of the most consequential climatic events during the Holocene. Its strong, devastating influence is well known for the Mediterranean, Egypt, Mesopotamia, and beyond. In a broader sense, the 4.2 ka event even marks the beginning of the Meghalayan, the youngest period of the Holocene. The geologic type locality or Global Boundary Stratotype Section and Point is located in Mawmluh Cave in the Indian Himalayas.

We conducted detailed geochemical, sedimentological, and palynological analyses on a 15 ka drill core from Lake Panch Pokhari in the Nepalese Himalaya to determine how Holocene climate history is reflected by changes in vegetation, landscape, and precipitation. This section is situated in an important geographical transition region. While the summer monsoon plays a dominant role in terms of precipitation, westerly winds dominate here precipitation and moisture in winter and spring and are therefore critical for plant growth and crop thriving early in the year. Higher snowfall in winter also affects the albedo of the Tibetan plateau and controls the strength of the summer monsoon.

In the pollen record, we can identify the 4.2 ka event by a decrease in summer monsoon related species but an increase in tree taxa associated with higher winter precipitation. This indicates that thee 4.2 ka event was accompanied by a profound shift in the relative strength of the winter westerly wind and the summer monsoon, which temporarily led to sustained changes in annual precipitation patterns. This appears to have strongly influenced the composition and species selection of crops grown by the Harappan culture in the northwestern Indian subcontinent. The late Harappan culture ended during a second climate event that again brought higher proportions of winter precipitation and lower monsoonal summer rains by 3.4 ka.

Protohistoric oases as a response to aridity? A view from Bronze Age northern Oman

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We present a case-study, centered on the development of oasis agricultural systems in Oman, to illustrate the complexities inherent in linking climate forcing and societal responses when working with ancient archives, particularly regarding questions of causality and synchronicity. The origin of oases in Oman is sometimes presented as an adaptative response to the onset of aridity at the end of the Holocene Humid Period around 5,000 BP. Many components of the oasis agricultural system seem to have first appeared in the region during the Early Bronze Age (ca 5,100–4,000 BP), including (semi)permanent settlements, crops, and water management. However, evidence for these is rarely found together, but rather spread across different archeological sites and dates. Furthermore, records relating to fluctuations in rainfall, surficial water and groundwater levels show asynchronous responses to aridity due to the resolution of recordings and the time lag of some phenomena. The onset of aridity, therefore, may start anywhere within a 1,000-year interval, depending on the archive employed. Further compounding the issue, it is challenging to disentangle climate induced- vs. anthropic changes in vegetation change in the zone of pastoral activities surrounding oases from site-based datasets.
Within the frame of the UmWeltWandel project, we have mobilized a multidisciplinary approach that includes archaeobotany, palynology, geomorphology, archaeology, and malacology, to study human-environment interactions in the EBA archaeological complex at al-Khashbah, Oman. We argue that a clear, well-dated tipping point in local paleoenvironmental records is required to situate any climate forcing event in time. We then demonstrate, using a range of examples including al-Khashbah, the chronological, archaeological and palaeoclimatological complexities inherent in trying to identify the origin of oases in Oman and question the immediate and causal character induced by the notion of “adaptative responses” in the study of this development.

Impact of Neoglacial cooling on human activity in West Greenland

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Present climate change is the most urgent challenge to the global population. However, this is not the first time that humans are confronted by climatic shifts that demand drastic changes in ways of life – or demise. We present a new, local reconstruction of climate at ancient Inuit hunting grounds in the UNESCO World Heritage area Aasivisuit-Nipisat, West Greenland. We use lake sediment and apply a wide palette of climate proxies, including: palynology, chironomid $d^{18}O$, lake chemical composition, and stable isotopes. In contrast to most of the existing climate reconstructions in Greenland, our record is focused on the last 1500 years, and we thereby offer a very high resolution of a period with drastic climate changes and high human activity in the area. Our multi-proxy approach offers a robust and detailed reconstruction and we find evidence of stable conditions followed by a cooling and drying trend - the Neoglacial cooling - that forced change of Inuit hunter-gatherers' migration patterns.

Collapse of the Maya civilization related to persistent drought

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A period of severe droughts between the eighth to eleventh century CE was unprecedented in Maya prehistory and played a vast role in the regional collapse of the Maya civilization. Previous paleoclimatological and archaeological studies suggest that the mechanisms behind the extensive drought periods could be attributed to solar variability, North Atlantic climate variability, a shift of the Intertropical Convergence Zone, El Niño southern oscillation (ENSO) variability, deforestation, changes in tropical cyclone frequency or changes to the interoceanic sea surface temperature (SST) gradient.

In this study, we aim to verify the above-mentioned hypotheses through analysis of our simulation for the last millennium using a fully coupled global climate model EC-Earth3. Global climate models have the advantage of demonstrating teleconnections in the climate system. Although the Maya lowlands are a small-scale region, the cause of regional climate change can be due to remote forcing.

In essence, a 300-year persistent drought during the eighth to eleventh century CE in Maya lowlands is observed in the EC-Earth last millennium simulation. Our analyses of different climate aspects identified several contributors to the persistent drought. The climate variability within the North Atlantic is reduced, ENSO variability is enhanced with more frequent El Niño events, the hurricane genesis is reduced in the eastern Pacific, and the interoceanic SST gradient between the eastern Pacific and the tropical Atlantic is enhanced. Changes in deforestation can not be detected in the reconstruction, and a slight increase in solar irradiance is negligible as they are the inputs of climate forcings in the model.

Vegetational responses to climatic trends, specifically droughts, during the Norse settlement period in Southern Greenland

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1. *National Museum of Denmark,* ***2.*** *Department of Geosciences at the University of Massachusetts,* ***3.*** *Lamont-Doherty Earth Observatory, Columbia University*

The Norse arrived in southern Greenland and were settled in farming communities for around 500 years before disappearing and a wide variety of causes have been suggested for their demise. Recently a study by Zhao et al. (2022) from sediments from a lake on a Norse farm identified an increase in the occurrence of droughts during the 15th century AD and suggested that these droughts negatively affected hay-making which kept the vital livestock alive through the winters. However, while the effect of droughts on local hay-making can be observed in recent years, the larger regional scale pollen data during the later Norse period contrastingly shows that concentrations of grass pollen increased during this period. To resolve this apparent dichotomy a high-resolution palynological reconstruction using the same lake samples gives the local pollen-influx data proximal to the settlement which is then compared to more distal vegetational reconstructions and existing climatic data.

Climate and cultural changes NW Arabia (Mid–Holocene)

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since 1972 when they had the first meeting the United Nations Conference on the Human Environment in Stockholm, Sweden,
and Twenty years later, at the historic Earth Summit in Brazil in 1992, the United Nations sought to help Governments rethink economic development and find ways to stop polluting the planet and depleting its natural resources, produced the Rio Declaration, which had 27 principles, which reflected human beings' responsibility for sustainable development.
the Convention of Combat Desertification, Dec. 1996. And other conferences and Conventions 1997, 2000, 2002, 2005, 2008, 2010, 2012, 2013, 2015, .. 50+ in Stockholm this summer 2022.
2022 witnessed serious effects of global climate change. Rivers and lake disappeared, aridity even in Europe. Higher temperatures. 15000 persons in Europe died last summer because of the global warming. thousands of forests hectares flamed up this summer. Heavy floods in dried areas.
After all, the international community has not succeeded in curbing the excessive consumerism of the earth's resources, and the systematic destruction of the ecosystem searching for global imbalanced welfare, nor has it imposed the necessary solutions avoid humanity what so called "collective suicide".
Water is playing an important role in the past and present in demography and civilizations. concentrated around water and shrinking far away from water. Qulban Bni Mura and Rajajil witnessed one of the most important water management systems and strategies in the northwest Arabia. the climate change of the mid - Holocene in the northwest Aribia during the transition to the aridity left behind water management systems and strategies. The paleo - environment, paleo - climate and climate changes have been affected on the water resources of the northwest Arabia. This forced the people to establish water management systems and strategies adapt and deal with the extreme environmental conditions and less water in the northwest Arabia. This contribution is shedding the light on the water management systems and strategies of the chalcolithic pre-oasis culture of the northwest Arabia, Furthermore It will clarify how human being part of climate change solutions in the past, while the human nowadays is causing of climate changes.

Session 138: Wet Environments and Human Communities: Interaction and Resilience in the Holocene and Antiquity

‘Where Land and Waters Meet’; 10,000 years of human eco-dynamics within a ‘Wildscape’

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Archaeological records indicate that humans have long been attracted to resources available within river and wetland ecosystems, with settlement and economic activities occurring around the wetland-dryland interface. Moving waters connect these places, weaving the threads of the landscape together, and impacting lifeways well beyond their boundaries.

Here, we explore changing wetland-dryland human eco-dynamics, across inter-connected river-mere-wetlands, to understand how these places were used and transformed over time. Our case study is the Humberhead Levels landscape, eastern England, where there has been a long history of palaeoenvironmental, geoarchaeological and archaeological study. Today the land cover is mostly intensive agriculture, with a few protected areas centred on the remnants of heavily exploited lowland ombrotrophic mires. Lidar imagery, historical maps, accounts, and the sediments underlying the fields tell a different story; until the 17th century, it was a landscape of inter-connected rivers, meres, wetlands and marshes, with extensive areas of open water, sometimes tidal, always deeply connected by sea and freshwater, with human settlement and activity clustered on islands of higher ground. The rivers and wetlands were extensively utilized throughout prehistory for their resources and as routeways, whilst in the Roman and historic periods they were transformed for navigation and control, then diverted, drained and canalized, representing a way of life and adaptation to living-with-water that can be traced back over thousands of years.

An extensive archaeological database has allowed us to infer the nature and focus of human activity and land use – from the Mesolithic to the post-Medieval period - whilst pollen records provide a land cover history. By reconstructing the temporal palaeogeography and dynamics of the ‘wildscape’ it is possible to understand the complex patterns of human activity, interactions and how these riverscapes and wetlands were used over space and time. The story that emerges is one that is intimately connected to the wetlands, distinctive and unique and yet widely connected beyond the wetlands themselves, whilst emphasising long-term continuity of human-environment relationships over time.

A combined geoarchaeological and bioarchaeological approach at Vix (Burgundy, France) to reconstruct human-environment interactions since the Iron Age: the case of the Fontaine des Abîmes

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The Hallstatt principality of Vix is above all famous for the burial mount of "*la Dame de Vix*" and its exceptional archaeological material, especially Greek and Etruscan imports. On a plateau overlooking the Seine River, a settlement with a quasi-urban spatial organization and monumental apsidal buildings unique for the period, was fortified by a vast network of ramparts (45 ha). From there, a local aristocratic power controlled the valley during the 6th and the beginning of the 5th centuries B.C.

This site of major importance for European Protohistory is located in a karstic region with several resurgences emerging in its immediate vicinity. However, questions related to the uses of these water sources remain little discussed. Through a study combining geoarchaeology, bioarchaeology and archeoecology, we aim to describe with high resolution, the relationships between the hydrogeomorphological and environmental evolutions of a karst resurgence, and socio-cultural practices linked to the water resource.

A 238 cm core was collected close to the spring at *La Fontaine des Abîmes*, less than 500 m from the famous tumulus. Geoarchaeological (stratigraphy interpretation, granulometry, geochemistry) and bioarchaeological analyses (palynology and carpology) were conducted on the core, as well as ^{14}C dating.

This integrated approach highlights changes in hydrological and environmental dynamics over the last two millennia. The alternation between clay decantation phases and organic sediment depositions reveals variations in the water regime. Landscape composition alternates between a forested environment (woodland edge/alluvial forest) and a more open environment (fields/meadows). Moreover, the association of biotic and abiotic assemblages with archaeological evidence provides information about the modalities of human activities at this site. The *Fontaine des Abîmes* area was strongly impacted by agriculture in the Iron Age (750-50 BC). Human impact seems also visible during Antiquity (50 BC-500 AD) when a change in depositional environment causes a transition from clay to peat. Then during the Middle Ages (500-1500 AD), palynological and carpological remains suggests a shift in land use towards pastoralism. Proxies used seem to have the same dates of their tipping points and this combined approach shows how increases in human impact may provoke rapid responses in the ecosystem.

Erosion history, landscape dynamics and human presence during the Holocene in the Lake Țaga catchment, Transylvanian lowlands, Romania

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Climate change is predicted to increase soil erosion worldwide, as a result of an increase in the frequency of extreme climatic events (e.g., torrential rains and droughts). The effects of climate change, superimposed on increasing anthropogenic pressure will affect all types of land use and ecosystem services, particularly in lowlands, which are densely populated and therefore more exposed to climate-related risks. Increasing erosion and landscape degradation are already visible in the lowland areas of Central-Eastern Europe, where there is little information on their past environmental dynamics and the extent of human transformation of these landscapes. This limits estimation of the potential future risks posed by environmental change in a warmer world.

Lake Țaga, in the Transylvanian lowlands holds a 7.2-m long sedimentary sequence spanning the mid-late Holocene, thus potentially allowing us to fill in knowledge gaps in the evolution of this area and potential drivers of landscape change. To reconstruct catchment erosion history, the sediment core was analyzed for elemental geochemistry, particle size and mineral magnetic proprieties to define erosion patterns, depositional characteristics and lake-catchment interactions. Furthermore, local archaeological surveys and published extra-local data on past fire disturbance, vegetation and climate dynamics contributed to the reconstruction of human habitation dynamics in relation to land-use/landcover change.

We found three intervals of greater erosion during the last 6000 years. Firstly, prior to 4200 yr BP, erosion was mainly induced by climate variability and the instability of river channels in the catchment. The second interval, between 3800-3000 cal yr BP, and the third interval spanning the last 1800 years of soil erosion and sediment deposition were driven by human activities, such as deforestation, the extension of agricultural land and finally direct intervention in the water body. In addition, two intervals of greater stability could be identified (4200-3800 cal yr BP and 3000-1800 cal yr BP), which coincided with negative NAO modes and lower than average temperatures.

The Taga Lake sediment archive offers new perspectives on landscape scale environmental changes and the processes of erosion and lacustrine deposition and their interaction with anthropogenic effects and climate variability on a millennial time scale.

Middle Holocene climate changes and human impact in Sardinia: the contribution of new geochemical proxy data

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Multidisciplinary palaeoenvironmental research has elucidating elucidated aspects of the relationships between human settlements and their environments across the Mediterranean region at times of rapid climate changes occurred during the Holocene. However, the climate history and the interactions between humans, climate, and environment in Sardinia, the second largest island of the Mediterranean, remain poorly understood. Building on and expanding from recent research in the Rio Posada basin, eastern Sardinia, this work discusses the results of geochemical and statistical analyses of sedimentary archives covering the last 8000 years BP. Firstly, Principle Component Analysis (PCA) was performed to understand the geochemical composition of lithostratigraphic units. Secondly, we tested the potential of geochemical ratios (Sr/Ba, Ti/Ca and K/Ti) to detect evidence of climate change in mid-Holocene lagoonal deposits. Whilst the PCA results showed that the geochemical variability of each lithostratigraphic unit follows a distribution linked to strong (weak) influences with geogenic and environmental-related elements, the unit of lagoonal facies yielded the highest variability and did not cluster according to a single factor influencing the geochemical distribution. This variability was subsequently framed by the results of the geochemical ratios that recorded a pattern of alternating peaks in the K/TI and Ti/Ca, which are synchronous with low (high) values of the Sr/Ba ratio. These developments occurred at periods of higher rainfall and erosion rates recorded across the western Mediterranean, including North Iberia and North Africa, between 7.5 - 7.2, 7 - 6.8, 6.3 - 6 ka BP. These findings show the potential of geochemical profiling to investigate past climate changes and offer new insights into Mid-Holocene human-interactions in Sardinia. Nevertheless, a higher sampling resolution and the comparison with different regional climate proxies are necessary to improve the reconstruction of the climatic history of Sardinia and of the societal responses to past climate changes.

From settled mainland to abandoned islands: how landscape transformation tested resilience of Neolithic inhabitants of the Oldenburger Graben wetlands, NE Germany

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In prehistory, the area of Oldenburger Graben comprised a Baltic Sea fjord and later a coastal lagoon. The Neolithic settlements located here and in the surrounding zone are some of the best-investigated in northern Germany. They have offered a substantial body of data on the material culture, built and natural environment, and human subsistence in the period from the end of the 5th to the first centuries of the 2nd millennium BC (the Nordic Early, Middle, Young and Late Neolithic). Situated next to and, for much of its history, connected to the Baltic Sea, the Oldenburg wetland area was significantly influenced by the post-glacial sea level rise resulting in the local evolution from brackish to marine to freshwater environment, with implications for the soil and vegetation cover. In this presentation, we show how the dynamic landscape shaped the nature of human activity and the duration of Neolithic occupation. First, we summarise the findings of geomorphological and palaeoecological investigations in the area, which enable a reconstruction of the changes in the environment in the time just before and during the Neolithic. Then, we look at the evidence of human habitation, food production, diet and cuisine using the data from archaeology (material culture), archaeobotany, food remains, human osteology and stable isotope analysis of botanical and human remains. We interpret diachronic changes in the size and number of domestic sites and the agricultural land use as adaptations to the declining landscape affordances, which tested the resilience of the local lifestyle. The abandonment of sites along the coastal mainland and on peninsulas-turned-islands may signal that limits of resilience were ultimately reached. We discuss the extent of adaptability of the Neolithic inhabitants of the Oldenburger Graben, and how the present can learn from the past.

Palaeoenvironmental dynamics and human-landscape interactions at the Bolsena Lake (Central Italy) between the 2nd millennium and 5th century BCE

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During the Late Holocene, wet environments faced remarkable changes in relation to rapid climate fluctuations and increasing human impact on ecosystems. The intricate interplay of climate, human history, and land-use systems stands as a multifaceted research subject, requiring the integration of different scientific disciplines with different perspectives on human-wet environment relationships.

The archaeological site of Bisenzio, located on the SW coast of the Bolsena Lake, represents an ideal testbed to investigate past environmental changes and their effects on the livelihoods of the human community that thrived between the 2nd millennium and the beginning of the 5th century BCE.

A transdisciplinary approach combining different investigation strategies and research methodologies, such as underwater cartography achieved through interferometric side scan sonar and UAS surveys, stratigraphic archaeological soundings, sedimentological and palynological analysis of sediment cores, as well as the study of in situ palaeobotanical and archaeozoological remains, allowed to delineate some preliminary insights on landscape changes, water resources, and the geo-hydrological network at Bisenzio during that time.

The high-resolution bathymetric surveys provided updated isobath contours for the nearshore zone, revealing a more articulated morphology of the lakebed than that highlighted by the relief made some decades ago. These new data improve our knowledge on the underwater region of the archaeological site enabling more accurate interpretations of the submerged functional structures.

The results of boreholes drilled along the currently emerged area have provided evidence of sedimentary sequences of high-energy streams, with relevant thicknesses containing fragments of ancient anthropogenic artifacts.

Exploratory pollen analysis of sediment cores from the offshore zone revealed a depositional hiatus that is coherent with high-energy environment in the proximity of the archaeological site. Preliminary chronological assessment, based on 3 radiocarbon dates, highlighted consistent results.

Palynological and palaeobotanical investigations of archaeological samples from domestic contexts provided crucial information on cultivated, ruderal, and synanthropic plant species related to human activities at the site.

This work offers an overview of the first results of the ongoing international 'Bisenzio Project' which aims to reconstruct both the salient aspects of palaeoenvironmental dynamics and resilience strategies implemented by humans in a changing ecosystem.

Plant subsistence on the lakeshore: exploring human-environment interactions through rich waterlogged plant remains

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The Late Neolithic settlement of Ploča, Mičov Grad, Lake Ohrid, North Macedonia, is one of many lakeshore sites in the southern Balkans. The area's location renders it pivotal for understanding the establishment of agriculture in temperate continental Europe. Despite this, wetland sites in this region have rarely been subject to systematic archaeobotanical study. As part of the international and inter-disciplinary ERC-funded EXPLO project, excavations at the pile-dwelling site of Ploča, Mičov Grad aim to shed light on the way its occupants adapted Neolithic subsistence practices to their lakeshore setting. Here, a cultural layer up to 1.7-m thick, associated with the settlement, was extracted through lake cores, rich with waterlogged archaeobotanical material and dated to the mid-5th millennium BCE. This record shows that the community used a wide range of plants including cultivated cereals and pulses, oil-seed crops and gathered fruits and nuts. The settlement lay within a mosaic landscape, centred upon the wetland interface between the oligotrophic lake and the imposing Galičica mountain range. The excellently preserved botanical remains attest to clear recurrent patterning in land and plant use by a lakeshore community in this diverse landscape.

Holocene human impact on different altitudinal belts in Julian Alps, Slovenia

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Lake sediments are natural archives of long-term changes in the sensitive alpine environment. Climatic fluctuations and human influence contribute significantly to these changes, affecting vegetation, sedimentary processes around the lake and the chemical state of the lake. In the area of the Julian Alps (southeastern Alps), palynological, sedimentological and geochemical analyzes were carried out on three lakes at different altitudes (Lake Bohinj, 520 m a.s.l., lowland; Lake jezero na Planini pri jezeru, 1450 m a.s.l., montane belt; Lake jezero v Ledvicah, 1830 m a.s.l., subalpine belt), mainly, to compare the main factors affecting environmental changes at different altitudes.

Economic activities drove people to alpine environments, where they exploited the environment for various purposes. In the highlands, the appearance of anthropogenic indicators (*Plantago lanceolata, Sporormiella*) points to the beginnings of pastoralism already in the Neolithic, around 7500 BP. In the Early Bronze Age human impact increased, which is reflected in more archaeological sites, and coincides with other alpine regions. At Lake jezero v Ledvicah two fire events occurred (1800 and 1100 cal. BP), possibly to expand pastures. Around 430 cal. BP pastoralism in the montane belt became so intensive that caused major eutrophication of the Lake jezero na Planini pri jezeru.

In the Iron Age, the lowlands were probably more densely populated than the highlands with many important archeological sites. Increasing human impact probably resulted in major deforestation in the area in order to obtain enough wood for metallurgical purposes, which caused erosional processes in the lake. In the lowlands and montane belt, human-induced erosion and eutrophication significantly affected the lakes environment. In contrast, Lake jezero in Ledvicah in the subalpine belt, remained largely unaffected despite the recognized human influence from prehistoric times. Thus, comparing human impact at different altitudes, shows that it began earlier at higher altitudes, while it had greater impact on the lake's chemical state in the lowlands and montane belt.

Palaeoenvironmental and land-use reconstruction at the Neolithic site of Palù di Livenza (Northern Italy): a palynological perspective

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Palù di Livenza is a Neolithic pile-dwelling site, inscribed in the UNESCO World Heritage List since 2011. Investigations coordinated by Soprintendenza ABAP-FVG brought to light an impressive amount of archaeological and palaeobotanical data for the knowledge of the life in a wetland zone during the Neolithic. The Palù basin is a wet site that recorded environmental transformation through time and also the phases of early Holocene are preserved, that are rarely present in other sites of Northern Italy. The palynological studies in these contexts can be particularly informative because pollen is very well preserved and abundant in peaty sediments and its analysis allows to reconstruct a clear image of the vegetation and its changes through time. In this study, we present the palynological analyses performed on three sequences, two sampled on-site and one cored off-site. The on-site record (40 samples) come from trenches inside the archaeological site, while the off-site record (21 samples) was cored in the basin of the Livenza, 300 meters south of it, up to a depth of 6 m. On average 300 pollen grains per sample were counted. In the most ancient layers of the off-site sequence, a high presence of arboreal pollen (AP) is found, indicating a forested environment dominated by the mixed oakwood and some hygrophilous taxa, suggesting the presence of few wet areas around the site. From the middle of the sequence, the oakwood gradually decreases in favour of the hygrophilous taxa (both arboreal and non-arboreal taxa), indicating the establishment of a wetter environment. Cereals, API (Anthropogenic Pollen Indicators) and LPPI (Local Pastoral Pollen Indicators) are present throughout the sequence in little but significant amount. A comparison with the analysis of the on-site records is useful to understand the range of the human influence and to better characterize and quantify the human impact on the vegetation surrounding the site.

This study is included in a PON project aimed at reconstructing the biodiversity, the environment and the human/environment dynamics in Northern Italy from the Neolithic period to the end of the Bronze Age.

A 5 thousand-years history of environmental changes in the Argive Plain (Peloponnese, Greece) inferred from the new pollen record of Lake Lerna

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The study provides new pollen data from a sediment core taken in the area of Lake Lerna (Peloponnese, Greece). We have combined palaeoenvironmental and archaeological evidence from the Argive Plain, in addition to the palaeoclimatic reconstruction obtained from isotopic data of the same core and other regional proxies. Our aim is to reconstruct the environmental history of the region dominated by human activities already since the mid-Holocene.

The core recovered in 2016 has a total length of 5 m and covers the last 5000 years. The age-depth model is based on 6 AMS radiocarbon dates of plant remains and 2 dates of organic-rich sediment. The analysis of pollen grains and other palynomorphs was carried out on 84 sediment samples. The mean sampling resolution is 6 cm and the mean chronological resolution is 76 years.

Results show that the interaction of climate with a variety of cultural, political, and socio-economic factors transformed the vegetation of the plain and caused its long-term degradation. Before ca. 4000 BP the coring site was a fen and oak woodland prevailed in the uplands, whereas cereals were cultivated in the plain. Afterward, despite local wet climatic conditions, inferred by the isotopic record, a forest retreat was evidenced coinciding with increased human pressure. In particular, activities linked to the presence of Mycenaean palatial centres modified the landscape and resulted in expanding pasturelands. In the lake the abrupt expansion of macrophytes suggests that human management possibly produced a permanent hydrological change. From the Archaic period, the increasing human pressure in association with drier conditions caused landscape instability. Roman times coincide with forest regeneration under wetter conditions, whereas the landscape was shaped by intensive olive cultivation and pastoral activities. An economic landscape primarily based on pastures was established from the Byzantine period onwards, stressing the relationship between lower precipitation and increasing pastoralism in the Peloponnese. The dominance of open environments continues until modern times, when conditions were drier, and the present-day wetland formed at the expense of the lake.

The human and lake at the Bronze and Iron Age sites located in the Samica River valley (western Poland, Central Europe) in multi-proxy palaeoecological records

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Water availability is among the crucial factors influencing settlement development. Palaeoecological reconstructions, based on numerous proxies from peat and lacustrine deposits, are vital to reconstruct past settlements and human impact on local forests and lakes. In this study, we focused on the archaeological microregion in Bruszczewo village in southern Greater Poland (western Poland; Central Europe), which was inhabited by people from cultures of the Bronze and Iron Ages organised around the vast former lake. In this study, analyses of pollen, non-pollen palynomorphs, plant macrofossils, geochemical, and sedimentological markers were applied to reconstruct human impact on local ecosystems. Our study revealed at least one period of lake transgression at ca. 1880-1690 cal. BCE. From that period, wooden construction was found at an archaeological site adjacent to the shoreline. It was interpreted as a fascine built to prevent houses from the lake waters and/or to stabilize the shoreline from erosion. A pollen-inferred increase in human impact was identified at ca. 1630-1570 cal. BCE, and it was probably related to the presence of representatives of Unetice Culture. At that time, *Carpinus betulus* became a much more important forest component, perhaps, at the cost of *Corylus avellana*. The next distinct acceleration of human activity, marked by pollen data (increase in Cerealia type, *Secale cereale* percentages), was identified at ca. 1020-910 cal. BCE (Lusatian Urnfield Culture). An increase in diatom concentration in lacustrine sediments was simultaneous to both stages of increased human impact. What is interesting, there were almost no diatom valves in the sediment layers parallel to periods of (pollen-inferred) low human impact. This might be interpreted by the inflow of nutrients to the lake during periods of more intensive settlement, which stimulated a rise in water trophy (perhaps acidity). This improved conditions for the preservation of diatom valves in sediments preserving from their dissolving. The distinct lake terrestrialisation was identified between ca. 810±30 cal. BC and 790-540 cal. BC, but this did not weaken the human activity on former lake shores, as revealed by pollen and archaeological data.

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Reopening the case for a climate-induced population decline during the Late Bronze age Solar Minimum: Insights from an annually-resolved lake record.

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There is significant interest in the resilience of past populations to abrupt climate change and environmental stress. While the postglacial period is relatively stable, several widespread environmental downturns with important socio-economic impacts, are recognised to be linked to different climate forcing mechanisms. One event that has been the focus of significant attention, occurs around 2.8k cal. BP, coincident with the Homeric Grand Solar Minima (GSM). Debate surrounds the association between the timing of the solar-induced abrupt climatic oscillation and an observed population collapse at the end of the Bronze Age in northwestern Europe. Given this period falls within the ^{14}C calibration plateau, records with robust and precise chronological control are required to evaluate human responses to rapid climate and environmental change. Here we present a multi-proxy study of a unique varved record from the British Isles in the context of this discussion, Diss Mere, Norfolk. The Diss chronology, based on varve counts, cosmogenic dating (^{14}C and $^{9}Be/^{10}Be$) and tephrochronology provides unprecedented chronological control and a synchronisation tool to compare the Diss Mere record with other sites. We present a diatom-based wind record, a stable isotope-based hydrological record and a pollen-based landscape reconstruction from the same sediments, which allow us to compare the timing of the solar forcing, climatic and environmental response with minimal chronological uncertainty. We have remodelled existing radiocarbon dates for the British and Irish archaeological sites, along with data for East Anglia and show evidence for a Bronze Age population decline according to the most updated IntCal20 curve. Our results indicate the climatic response was synchronous and in-phase with the GSM and the regional population decline. Locally, palynological and spore data suggest that the climatic change did not have a significant impact on the vegetation but indicates a coeval reduction in human pressure on the landscape. Therefore, our study calls upon the chronological reassessment of the event in records and reopens the potential for a direct solar induced climate shift to impact on populations in Late Bronze Age Europe.

Landscape change during the Roman period in Southern Britain at Fishbourne Roman Palace

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Britain's past tells a tale of a human impacted landscape throughout the Mid to Late Holocene. Notable changes often occurred during periods of cultural exchange such as in the Bronze Age and Roman invasion. During the mid to late Holocene, a distinct trend of woodland clearance was observed. Forest previously dominated by *Quercus, Corylus* and *Alnus* was cleared with high levels of Poaceae pollen indicating a more open environment. The Roman invasion of Britain has previously been found to have impacted landscapes by intensifying farming efforts and through the introduction of exotic taxa. There is, however, a relative paucity of palaeoecological records covering the Roman period from the South of Britain.

Fishbourne Roman Palace, constructed in 43 AD, expanded upon in 73 AD and abandoned in 270 AD, is a site of spatial and temporal significance as it is one of the first Roman sites in Britain. Pollen was recovered from excavations of the site in 1971 and 2002, but due to less-than-ideal conditions for pollen preservation it was not abundant and there was evidence of preferential preservation of taxa with thicker walls. Salt marsh sediments, however, have a higher likelihood of yielding well preserved pollen due to their water-logged, anoxic nature. A sediment core of 193 cm was taken from salt marsh sediments 1km from Fishbourne Roman Palace, on the western bank of the Fishbourne Channel. The sediments are composed mainly of fine silts and clays containing some macro plant remains. A radiocarbon date from a piece of wood recovered from the core from 160 cm depth returned an age of 200 – 400 AD, with the base of the core therefore likely capturing the very start of the Roman invasion of Britain.

Pollen and charcoal records from these salt marsh sediments will be presented and used to reconstruct landscape scale changes associated with the Roman construction, occupation and abandonment of Fishbourne Roman Palace. By developing our understanding of the past of the British landscape, current debates around the conservation of heritage sites, including topics such as rewilding, can be informed by this long-term perspective.

Peruvian wetlands as archives for pre-Hispanic responses to late-Holocene climate and environmental change

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Wetlands located within the key agricultural belt of the Peruvian Andes (3000-4000m a.s.l), provide valuable records for socio-economic responses to climate and environmental change during the Late Holocene. Both previous studies and our recent research has illustrated that pre-Hispanic societies were able to cope with periods of major climatic variability, such as during the Medieval Climate Anomaly (MCA) and the Little Ice Age (LIA), by adapting water storage and transportation networks (reservoirs, canals, water catchment features and wet pastures) and agricultural practices (construction of terraces, multi-cropping, burning, and agroforestry). Communities responded to variation in natural resources, such as water availability, by modifying wetlands and constructing reservoirs. Wetlands would have acted as a buffer for ongoing climate change, providing a source of water for irrigated agriculture. The palaeoenvironmental records therefore indicate an apparent stability with continuous land-use throughout prehistory. Some of these wetlands also show evidence for human modification and adaptation of natural basins in order to increase water storage capacity and capitalise on periods of increased precipitation (e.g., LIA). This, in turn, would have provided greater water security for growing populations during periods such as the Late Horizon, when the Inca empire was expanding across large parts of Peru. We have provided an improved understanding of these human-wetland interactions in the Peruvian Andes using high-resolution analysis from a transect of sites across different environmental zones. We will present the results from a new multi-proxy study using radiocarbon-dated sediment geochemistry, pollen and non-pollen palynomorphs, alongside phytoliths and archaeological evidence from agricultural terraces. These records have demonstrated the potential of using mid-high-altitude wetlands for the detection of both longer-scale regional climate variability (MCA and LIA) and short-term climatic fluctuations (El Nino). Understanding how pre-Hispanic societies interacted with wet environments in the past is important for future land-use, water, and soil conservation practices. The future preservation of these wetlands is also highly important for both climate change regulation and for conserving a valuable archive of human-environment interactions.

Wet and Dry: a comparative approach to environmental evidence from the broch of Tirefuir and the nearby loch of Balnagowan.

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This-presentation-will-compare-the *dry* evidence-from-the-stratigraphy-of-Tirefuir broch midden-and-the-*wet* evidence-from-the-pollen-profile-of-the-loch-of-Balnagowan, a-mere 500 m from-the-archaeological-site, from-the-island of-Lismore, located-close-to-Oban-in the-west-of-Scotland. Recent research has calibrated a time series from both these locations, and the-paper-will-focus-on-the-period-400 BC-to-600 AD to-interpret-the complementary-evidence-from-the-two-sequences-towards an understanding of human interaction with the local environment, in-all-its-dimensions. The-island-has-a-distinctive limestone-geology-complicated-by-igneous-and-basaltic-intrusions-which-are-detectable in-the-isotopic-base lines, drawn-from-soil and-plants. The island-is-accessible-at-the-northern-end-across-a-strait of less than 1 km (with some intermediate islands), with relative ease at an appropriate time of the tide.

The-Balnagowan-pollen-sequence-covers-the-late-Glacial-and-much-of-the-full-Holocene, but-for-the-sake-of-this-comparison-we-concentrate-in-this-paper-on-the-part-of-the-later Holocene-contemporary-with-the-main-occupation-of-the-broch. For-this-purpose, radiocarbon-dates-have-been-applied to refine this period. The main arboreal decline on the island appears to have taken place at about 3900 BP (1950 BC). By the time of the occupation of the broch in about 400 BC (2350 BP), there appears to have been an open landscape with a light birch, alder, hazel coverage alongside a substantial presence of heather and grasses. The appearance of cereal pollen (barley) appears to coincide broadly with the arboreal decline and is identified through the phase of occupation at the broch. New evidence of fungal spores from the same palynological horizons have enhanced the environmental picture with evidence of grassland indicators covering the past 3600 years and two of these key dung fungal spores, *Sordaria* and *Sporomiella*, typically indicate the presence of grazers and are associated with domestication in archaeological contexts.

The midden of the broch of Tirefuir has provided a good complementary understanding of the consumption and patterning of resources from the local island landscape and its near continent, by combining evidence from plant macrofossils, charcoal and animals. The principal domesticates (sheep, cattle and pig) have been studied not only in terms of their relative proportions and age/sex profile at death, but also by isotope analysis (carbon, nitrogen and strontium). aDNA studies of the sheep and cattle will also provide complementary evidence of their place in the broader genetic mapping of the British Isles. Alder, birch, hazel, ash, Scot's pine, cherry type, oak and willow were present amongst recovered charcoals. Oats and Barley were prominent amongst the cereals. Cattle were the dominant domestic species followed by sheep and pigs. Some evidence of site formation processes is provided by micromorphology.

The-presentation-will-bring-together-these-complementary-data-from-wet-and-dry-sources-to-produce-the-best-case-comprehensive-model-of-human-interaction-with-the-environment-for-this-small-island-community-of-Argyll-during-the-Iron-Age.

Session 139: Holocene Global Landuse

The "first farming" in ALCC modelling – the challenges posed by terminology in past land use and land cover modelling

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Our ability to accurately reconstruct past environments is critical for understanding many aspects of the earth system. Information on past land use is currently provided by anthropogenic land-cover change (ALCC) scenarios. ALCC scenarios provide data essential for earth system modeling of the past, present, and future. The relationship between the first and last part of this is critical – how does past data inform future modelling? Historical and archaeological scholars are key to the development of better ALCC scenarios and earth system models. Throughout the Holocene, the development of new lifeways including agriculture, pastoralism, arboriculture, urbanism, extractive industries and all the nuances within these, created new ways in which the landscape could be, and was, impacted and changed. These developed alongside and in addition to the myriad ways that the many hunter-gatherer-fisher-forager lifeways and land use could and were changing environments. Understanding how and, particularly for earth systems models, when new land uses came about and the impact they had on land cover is essential. While ALCC scenarios have been widely applied in earth system modeling studies, they are subject to major limitations, including differences in proxy scale, a lack of incorporation of past surplus or capital accumulation, and most importantly, significant differences between ALCC scenarios with regard to starting assumptions. As a case study, the deep archaeological "origins of agriculture" debate bring with them temporal and regional variability in terminology and 'markers' for identifying this 'horizon' in the human past. The blurred nature of the boundaries between hunter-gatherer-fisher-foragers, early cultivators and early agriculturalists seen in archaeological discussions has yet to be fully translated to ALCC scenarios, and has resulted in a diversity of approached and boundaries forming. In this paper the nuances of the terminologies used in three ALCC modeling approaches are explored and how the concepts of 'agriculture' and the 'first agriculture' are being approached. The implications of defining and pining down these messy processes are considered, and how this much debated topic can be integrated into the clean ALCC and earth systems models desired is explored. The result is both ontological and epistemological issues for modelling down-the-line.

Pollen-based reconstruction of land cover change in northern China during the Holocene

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Fossil pollen data are essential for reconstructing ancient vegetation and land-cover changes. Here, we propose a novel methodological strategy to reconstruct the regional land-cover and actual plant cover from pollen assemblages using MAT-estimated actual vegetation cover to correct the REVEALS-estimated cover of individual plant taxa. Subsequently, we reconstructed the land cover change in northern China during the Holocene using the above strategy. At the regional scale, the vegetation composition of the past 6,000 years and the spatial dynamics of main land cover types (*Pinus*, coniferous trees, deciduous trees, grassland, and bare ground) in 6ka, 3ka, and 0ka were obtained. The results show that the land cover changes may have been spatially migrated due to the influence of climate in the past 6000 years. Meanwhile, the reduction in vegetation cover, especially forest cover, may have been significantly influenced by human activities. At the local scale, we reconstructed the land cover changes in the Daihai basin and the alpine Gonghai area during the Holocene, which reveal diverse vegetation succession patterns in different regions and geomorphologic contexts. We propose that changes in the intensity of human activities was a major cause of the observed regional disparities in vegetation succession. In larger basin/plain areas, the favorable climatic conditions of the mid-Holocene promoted increased human activity; while later, population pressure, the increased demand for resources, and political factors may have triggered the diffusion of human populations from basins to the mountains or previously undeveloped areas, with resulting effects on their vegetation succession.

Was there a pre-modern forest transition in the eastern Mediterranean?

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The ‘forest transition theory’ describes the historical turnaround in land use from net forest loss (i.e., deforestation) to net forest gain (Mather *Area*, 1992). It has been linked to scarcity of woodland resources at the time of the forest minimum (e.g., timber and charcoal), and a subsequent shift to fossil fuels for energy supply. The timing of the forest transition has been region-specific, for example, taking place during the early 19th century in northern Europe linked to the Industrial Revolution. In this region it followed a multi-millennial trend towards net forest loss that is clearly recorded in pollen records (Roberts *et al.*, *Sci Rep.* 2018). A similar long-term decline in forest cover is evident in pollen data from the west and central Mediterranean (Woodbridge *et al.*, *J Biogeog*. 2018; Fyfe *et al.*, *VHA* 2018). However, synthesised pollen data show a different trend in parts of the eastern Mediterranean during the Late Holocene (Roberts *et al.*, *Holocene*, 2019). In south-central Anatolia and the southern Levant, for example, arboreal pollen (AP%) reached a minimum during Classical times, and a net increase in woodland cover is inferred for the last ~1300 years. Consequently, we can ask the question of whether the forest transition here occurred in pre-modern times, unrelated to a stage model of economic development. Instead, woodland recovery was triggered by agricultural land abandonment in Late Antiquity, which led to landscape “rewilding” and reforestation. This model does not take account of tree crops, such as olive groves, which peaked during the Beyşehir Occupation land-use phase (>2300-1300 Cal BP), nor does it reveal shifts in species composition of secondary woodland towards taxa such as pine and evergreen oak and away from deciduous trees along with conifers, such as cedar and fir. In reality, the decline and recovery of eastern Mediterranean forests during the last two millennia represents one of several cycles of deforestation and afforestation that have taken place in this region since Neolithic times.

12k-6k in the Korean Peninsula, a big data synthesis of land use and climate change across the Holocene

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Human societies have managed and modified Earth's landscapes for thousands of years, altering global patterns of biodiversity, ecosystem functioning, and climate. Anthropogenic modifications and land use accelerated with the emergence of agriculture. This pace of change will only accelerate further with the land changes to come under the 4th Industrial Era. The extent, trajectory, and implications of these changes are still not fully understood, and the implications of our long-term history for future climate change predictions need more research. The trajectories of change are needed to accurately model our impacts now and going forwards, and historical and archaeological scholars are key to the development of these Anthropogenic Land Cover Change (ALCC) scenarios and earth system models. Such important classification and documentation of past land cover and importantly land use practices has been done in many regions, but in the Korean Peninsula systematic data synthesis remains to be done in a comprehensive way that links human land use to changing land cover. Through the methods of the Land Cover 6k project, the Korean Working Group has been approaching land use change over the Holocene, mapping and modelling changes with a view to providing data for ALCC scenario building. In this paper we outline the mapping from the first stages of this project focusing on 12k and 6k. These timeslices show the early Holocene warming period and the arrival of domesticates into the Korean Peninsula. The impact of changing food availability and lifeways is mapped relative to settlement patterns and land uses, comparing traditional datasets (settlement distributions and excavation data) with C_{14} distributions. In particular the issue of data availability and accessibility is discussed in a region fraught with the impacts of modern geopolitics.

Early to Mid-Holocene Land Use Transitions in South Asia: a New Archaeological Synthesis of Potential Human Impacts

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While it is clear that current human impact on the earth system is unprecedented in scope and scale, much less is known about the long-term histories of human land use and their effects on vegetation, carbon cycling, and other factors relevant to climate change. Current debates over the possible importance of human activities prior to the last few hundred years cannot be effectively resolved without evidence-based reconstructions of past land use and its consequences. The goal of the PAGES LandCover 6K working group is to reconstructing human land use and land cover over the past 12,000 years. In this paper, we present the first large-scale synthesis of archaeological evidence for human land use in South Asia at 12 and 6kya, a critical period for the transition to agriculture, arguably one of the land use transitions most consequential in terms of human impact on the Earth system. Perhaps the most important narrative we can pick out is that while there are some shifts in land use across these timeslices, hunter-gatherer-fisher-foragering remained the dominant land use, and within this there was a mosaic of strategies exploiting diverse and complex landscapes and ecologies. This is not necessarily a new conclusion – it is not new to state that South Asia is comprised of many niches, but demonstrating the deep time history of how people have adapted to these and adapted them is an important step for modelling the impacts of people and thinking about their footprints in a longue-duree perspective. Despite the new development of food production by 6kya, by overall area, foraging life ways continued as the dominant land use practice into the 6kya time slice. This is not to say that the development of agriculture and food production was not unimportant – it is the beginning of a land use that eventually comes to dominate the sub-continent, but at 6kya is restricted to specific contents. Across 12kya to 6kya and different land uses the use of mosaic ecologies, diverse strategies and the importance of water as a resource stand out as shared themes.

Human-Environment Dynamics Through the Holocene in the Mourne Region, Northern Ireland

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Uplands are widely perceived as marginal within the landscape. This is not solely due to their geographical isolation; upland environments are highly susceptible to the negative effects associated with periods of climatic deterioration. A rich archaeological record, however, attests to human presence in uplands through the Holocene, though little is understood about the chronology and nature of activities, critically raising questions of whether, and if so to what extent human agencies shaped upland landscapes. Here, we examine human-environment interactions in the context of the Mourne Mountains, Northern Ireland. Existing palaeoenvironmental research shows that a wooded landscape existed in the Mourne uplands in prehistoric times. This starkly differs to the heath-covered slopes present today, but the natural and/or human agencies which shaped this landscape remain uncertain. Through palynological analysis of blanket peat deposits from across the region, this study seeks to disentangle the environmental and human past of the Mourne uplands during the Holocene. Deep peat sequences illustrate the long-term vegetational and climatic history of the region. Palaeoenvironmental records collected from the vicinity of archaeological and historical sites in the Mourne uplands and adjacent lowlands provide insights on the environmental footprint of past occupation and land-use. This multi-scalar study enables the nature and periodicity of human activity to be contextualised against the long-term evolution of the Mournes landscape and address questions of how past populations interacted with their environment and fared under climatic stresses. This work considers the resilience and adaptability of 'marginal', upland communities to climatic and in turn environmental change, providing lessons for present and future populations who face pressures similar to those of societies in the past.

Vegetation responses to exploitation of mountainous areas in the Iron Age and Middle Ages

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People have always used mountains, but their impact on vegetation was probably minor until transhumance practices came into use, in Norway especially from the Iron Age (the last ca. 2000 years). The utilization and occupation in the Iron Age and the Middle Ages underwent several changes due to climatic conditions, demographic patterns, social and economic changes. The material from mountain regions, especially the activity up to the Viking Age, has mainly been interpreted as seasonal occupation, linked to the nearby low-lying agrarian societies by the fjords and main valleys. The establishment of farms and population growth in the first part of the Early Iron Age resulted in limited areas for cultivated fields, pastures, and fodder collection on and around the farms, influencing the use of the mountain areas. The increasing utilization of mountainous landscapes is also emphasized as important elements in the development of political centers in the (Late) Roman Iron Age. From around AD 300 roman imports appear more frequently in some lowland areas. The cluster of the objects are often interpreted as economic and political centers that took part in long-distance exchange networks, were the products from the mountains, in particular iron and reindeer antlers, were central. All ironmaking in prehistoric and medieval Norway is based on bog ore. In South Norway most places where iron was extracted were in the lower parts of mountainous areas, which were wooded. Archaeological data, mainly house remains and iron production sites, and palynological data, including LRA-estimated vegetation cover and samples from archaeological contexts, from the Flåmsfjella in western Norway, are presented. Utilization of mountain resources, tree cover changes and habitations/settlements in a long-time perspective, are discussed, with emphasis on the Iron Age and the Middle Ages. We specific address questions of when animal husbandry/grazing and iron extraction/making are established in the landscape – does this happen gradually or abruptly and is it possible to identify periods of more intensive use by combining our datasets.

Session 140: Quantifying climate change in Australasia: challenges and opportunities

Two glacial cycles of terrestrial paleoclimates from maar craters in northern New Zealand

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Continuous and high-resolution records of terrestrial paleoclimate spanning at least the Last Glacial Cycle (LGC) are scarce in the Southern Hemisphere mid-latitudes. Contained in the deep maar lakes of the Auckland Volcanic Field (AVF), Auckland, New Zealand, we have suitable records of deep lake sedimentation that span back to at least 193 ka that provide the continuous and laminated sediment records required for the identification of abrupt climate events in addition to the millennial-scale climate cycles. We have developed robust age models for the Pupuke (ca. 0 to 50 ka), Orakei (ca. 15.6 to 132 ka) and Onepoto (ca. 9 to 193 ka) maar lake sediment sequences with chronologies underpinned by AMS ^{14}C, luminescence dating, tephrochronology, magnetic paleointensity times-series and meteoric ^{10}Be influx. In addition, the multi-method refinement of the dating of these maar lake sediment records, in tandem with the repeated occurrence of well-dated marker tephra layers from multiple volcanic centers in most AVF maar lake sequences, allowed the refinement of the age models for the less well-dated maar lake sediment cores. These well-dated AVF maar lake sequences provide the fundamental frameworks for high-resolution multi-proxy paleoclimate analyses from northern New Zealand that span the LGC. The approach includes: micro-XRF scanning with elemental variability-inferred lake water column stability and sediment influx events; thin-section micro-facies characterization of depositional units, and the nature of rapid microfacies changes at facies boundaries; organic matter TOC, δ^{13}C, TN and δ^{15}N, pollen-inferred Mean Annual Temperatures; and biomarker-inferred past temperature and precipitation variability. The main aim of the project is the identification and search for climate teleconnections regionally, between the southern polar region and the Southern Hemisphere subtropics, as well as to search for inter-hemispheric climate linkages. Our finely laminated and well-dated AVF maar lake sequences retain the properties required to identify not only of past climate events and their timing, but also their drivers so that they constitute valuable records of LGC paleoclimate from the southwest Pacific region.

30-years of paleoenvironmental variation in the northern Great Barrier Reef reconstructed from Little Ice Age giant clam shell geochemistry

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The Little Ice Age (LIA) was a cold climatic interval from around 1300 to around 1850 CE. Most palaeoenvironmental reconstructions of the LIA come from high-latitude, Northern Hemisphere continental archives, including ice cores, tree rings, and lake deposits. There is a significant gap in our understanding of the effects of the LIA in the Southern Hemisphere marine environment. This study begins to fill this research gap by providing LIA-aged high-resolution marine proxy archive from the northern Great Barrier Reef.

Giant clams (*Tridacnidae* spp.) have a widespread distribution in the subtropical-tropical Pacific region. Compared with other archives, giant clams have advantages including high growth rate, clear increment bands and long lifespans, enabling long continuous reconstructions. The clear annual and daily shell increments can provide monthly, and even ultra-high resolution (daily), palaeoenvironmental reconstructions. By analysing the geochemical composition of giant clam shells, we can faithfully reconstruct palaeoclimate records, including SST, SSS, DIC, daily light cycles, rainfall, marine primary productivity and extreme weather events.

In this research, we have used multiple traditional and novel techniques, including microscopy, XRF, EPMA, AMS ^{14}C dating, IRMS, ICP-AES and LA-ICP-MS to analyse LIA giant clam shell growth patterns and geochemical compositions (δ^{18}O, Sr/Ca, Mg/Ca, Ba/Ca) to reconstruct seawater parameters and environmental changes in the northern Great Barrier Reef (GBR), Australia. Our initial results show that the shell records a 28- to 30-year palaeoenvironmental snapshot. The reconstructed LIA temperature range is □2 □ lower than modern instrumental records from the northern GBR and □0.6 □ lower than the average temperature between 1000 CE ~ 2000 CE. The Sr/Ca ratio results provide information about whether the solar output was lower during the LIA, whilst Ba/Ca ratios provide indications of rainfall or extreme weather events in this area during the 30-year snapshot. This project provides much needed ultra-high-resolution LIA palaeoenvironmental reconstructions from the Great Barrier Reef, enabling us to better assess the potential drivers of the LIA and its impacts on the Southern Hemisphere.

Kimberley monsoon rainforests - new Holocene palaeoenvironmental records from northwest Australia

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The Kimberley in northwest Australia is a region of archaeological significance, with a long history of human habitation accompanied by a long and diverse sequence of rock art. Understanding the climatic history of this region through the late Quaternary provides important environmental context to the archaeological history and insight into the spatial and temporal variability of the Indonesian-Australian summer monsoon, yet developing palaeoenvironmental records from this region is challenged by the ephemeral nature of lakes and wetlands. Speleothems and mound springs have been used as palaeoenvironmental archives in the Kimberley, but further records are needed to discern spatial variability and to strengthen palaeoclimate modelling of the Australasian region.

Monsoon rainforests in the Kimberley are small, discrete patches of diverse vegetation embedded in a eucalypt savanna landscape. These ecological communities are significant for their species richness, their role as a refuge and food source for fauna, and as a cultural resource for Aboriginal people. Rainforest taxa have persisted in the Kimberley through arid periods in the past, as evidenced by the presence of rainforest taxa in the macrobotanical record from Carpenter's Gap for over 47,000 years. However, little is known about how the extent of these rainforests, and their consequent availability as a resource, has varied through time. The sediments accumulating at rainforest patches provide an opportunity to study not only variability in the rainforests themselves, but also the surrounding savanna environment.

Here, we present records of environmental variability from the sediments of three monsoon rainforest sites. Variability in the abundance of rainforest taxa and changes in fire activity through time, inferred from pollen and charcoal preserved in the sediment, indicate changes in rainforest extent associated with regional environmental conditions. These records, in conjunction with previous speleothem and mound spring palaeoclimate records, elucidate monsoon variability, and provide insight into the environment experienced by inhabitants of the region through the Holocene.

The age and climatic significance of block deposits in southeast Australia

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Pleistocene glaciation was restricted in Australia to only the highest parts of the Snowy Mountains and Tasmania. However, periglacial activity was much more widespread. Periglacial landforms can be found down to 600-700 m in the Southern Tablelands and lower than this further to the south. Block deposits in the form of blockstreams and block slopes become common at higher elevations. Because of their association with freezing, block deposits hold considerable potential to quantify past climate change, but their dating and interpretation has been controversial. In this talk we will present new findings from a dating and mapping campaign of both high and low elevation block deposits in southeast Australia. The lowest altitude periglacial deposits have been identified on Black Mountain in Canberra and on the Southern Tablelands. The deposits constitute scree slopes, and associated alluvial fans and valley. Their age of formation was restricted to the coldest parts of the last glacial cycle. In Victoria, large-scale deposits occur above 900 m in the Mt Hotham region. The morphology of these deposits and their surface architecture supports their formation involving large-scale frost heave. 3D modelling supports the idea that pits in the surface are ice-melt collapse features. We present new exposure ages for blocks in these deposits using the cosmogenic nuclides ^{36}Cl and ^{10}Be. The re-establishment of forest at the end of the Pleistocene in the area is dated using radiocarbon. The deposits formed during the last glacial cycle and were not restricted to the last glacial maximum. Based on modern analogues, we estimate that mean temperatures were at least 8 °C colder than at present when the deposits formed.

Disentangling drivers of environmental change in Alpine Australia: A multi-proxy approach to understanding climate- and anthropogenic-driven change in the Holocene

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Disentangling the effects of climate change and anthropogenic activities on the environment is a significant challenge in palaeoenvironmental research. Alpine ecosystems are particularly sensitive to environmental change and are therefore ideal places to study long-term human-environment interactions. This study reconstructs landscape evolution in the alpine region of south-eastern Australia since the late Holocene by analysing pollen and spores, charcoal data, µXRF results, and physical proxies from Lake Cootaptamba (2048 m elevation). Charcoal data from 13 alpine sites show that local and regional fire activity peaked between 8000-5 ka cal BP. Data from Lake Cootaptamba and three pollen records from nearby sites above 1000 m show that both rainforest and wet sclerophyll vegetation types increased across the alpine region at this time.

These results suggest that an increase in precipitation in the mid-Holocene allowed vegetation communities to expand. The increase in regional precipitation and biomass led to increased fire activity. By 5 ka cal BP the climate regime in south-eastern Australia was influenced by increasing El Niño Southern Oscillation events, with variable precipitation leading to regional vegetation changes and a fire regime limited by biomass availability in the alpine zone. Paleolimnological results from alpine zones are compared to radiocarbon data from the Australian Archaeological Database to identify human presence during the Holocene. This study shows that over the last 2 ka cal BP increased erosion, vegetation community composition and changing fire regimes correspond with increased human occupation of the alpine zone. This multiproxy and multisite approach demonstrates how palaeoenvironmental studies from sensitive ecosystems can identify human traces and disentangle natural and anthropogenic drivers of change during the Holocene.

Reconsidering Holocene hydroclimate in eastern Australia

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Temperature reconstructions from the Southern Hemisphere mid latitudes indicate moderate Holocene variability. By contrast, Holocene hydroclimate reconstructions from the Australian mid latitudes, while limited in number, exhibit substantial centennial to millennial variation. Hence, understanding the nature and causes of this variability is important.

It has been argued that early to mid-Holocene climates on the coastal margin of eastern Australia were markedly wetter than present, but progressively dried over the last 5000 years. This drying has been invoked to explain changes in human population behaviour and density; increases in fire activity; and mammal extinctions on the Australian mainland. A variety of drivers is suggested for late Holocene drying. Of these, the El Niño –Southern Oscillation (ENSO) is the most prominent. In particular, strengthening of ENSO (notably the El Niño phase) has been used to explain climate drying from ~10 to 45°S.

Here, we present new data that prompt a refinement of these interpretations. A compilation of radiocarbon dates from perched lake sediments on K'gari (Fraser Island), in the subtropics of east-coast Australia, indicates a period of sedimentation hiatus interpreted as aridity from approximately 7,400 to 5,000 a. This, in many ways, directly contradicts the hypothesis that weaker ENSO resulted in climates wetter than today for this period.

An additional hydroclimate record from Lake Surprise, in the temperate volcanic plains of western Victoria, indicates a more variable early to mid-Holocene regional hydroclimate than previously inferred. This record, derived from diatoms, scanning XRF data and oxygen isotopes from aquatic cellulose, shows that the early to mid-Holocene (11,800 - 4,500 a) experienced substantial centennial-scale variability characterised by both the wettest Holocene climates, but notably some of the driest.

The study seeks to explain the differences between these localities (and existing work) by discussing the role of the southern westerly winds and the south-east trades

An 800,000-year record of terrestrial temperature in the Indo-Pacific Warm Pool

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The Indo-Pacific Warm Pool (IPWP), with its high sea surface temperatures and deep atmospheric convection, plays an important role energizing Earth's atmospheric circulation. Proxy records and climate model simulations indicate cooler and drier conditions in the IPWP at the Last Glacial Maximum (LGM) compared to modern. Climate model simulations point to greenhouse gas forcing as the dominant control on temperature in the IPWP during the last deglaciation. However, alternative forcings, including insolation, have been proposed to control temperature in the IPWP, and we do not have any quantitative terrestrial paleotemperature records from the IPWP that extend beyond the LGM. We produced an 800,000-year terrestrial temperature record from a continuous sediment record from Lake Towuti, located in the center of the IPWP on Sulawesi, Indonesia. The temperature reconstruction is based on the relative abundances of temperature-sensitive lipids that compose the membrane of bacteria (branched glycerol dialkyl glycerol tetraethers; brGDGTs). The Lake Towuti terrestrial temperature reconstruction covaries with global benthic d^{18}O rather than local insolation, pointing to greenhouse gas concentrations, ice sheets (albedo and/or topography), or sea level as the dominant control of IPWP terrestrial temperature. The covariation IPWP terrestrial temperature with global benthic d^{18}O during the past 800,000 years, highlights the importance of understanding the impact of both remote and local forcings on IPWP climate. Inferences from the climate model simulations, which identified greenhouse gas concentrations as the dominant forcing of temperature in the IPWP during the last deglaciation, can potentially be extrapolated to earlier in the Quaternary period. A dominant control of greenhouse gas concentrations on terrestrial temperature would raise concerns about how climate in the IPWP will continue respond to anthropogenic greenhouse gas emissions in coming decades.

Session 141: How can the Quaternary sciences contribute to scientific assessment of biodiversity, ecosystems, and nature?

Use-inspired paleo-perspectives are critical for saving the planet and building strong 21st century scientific careers.

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1. University of Michigan

The planet and its biosphere are under unprecedented threat from human activity, most notably via climate change plus unsustainable land and water-use. Few drivers of deleterious global change are slowing, and many are worsening at an accelerating rate. Strangely, many scientists – the ones who understand the threats and implications the most - are choosing to do little to ensure a more just and sustainable future for the planet. Quaternary scientists have the expertise to understand how the Earth system works and how society might avoid a future of large climate change, biodiversity crisis, and much more. Quaternary scientists also often have the knowledge needed to help build more resilient human systems and adapt to environmental change that cannot be avoided. More needs to be done to ensure that the paleoenvironmental perspective is tapped by society to build a just and sustainable future.

There are many ways Quaternary scholars can do more to serve society. Engaging with society to communicate and discuss the implications of science for society is critical. Expanding our research and education efforts to be more use-inspired and usable by society is critical. Ensuring all students getting a university education understand what's at stake and what can be done, no matter what careers they choose to pursue, is critical. The sheer number of Quaternary scientists in the world highlights the impact we all could have if we all work together to be a 21st century forces for change – we won't save the planet with scholarly publications and citations alone.

Over the last 20 years, paleo-perspectives have become integral to climate assessments, both IPCC and national. Now is the time for more scientists with understanding of Earth system behavior over the Quaternary to step up and ensure that biodiversity and ecosystem assessments are also strongly informed by paleoenvironmental science. The work is time-consuming, but it is also uniquely powerful in building strong international 21st century academic careers. Learning to communicate with society's decisionmakers is essential to having real impact and to saving the planet for future generations.

Quaternary extinction and colonization dynamics alter long-term functional trait diversity in Caribbean reptiles

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Reptiles have experienced significant biodiversity decline throughout the Quaternary, with extinction and extirpation events linked to anthropogenic impacts. At the same time, introductions of novel reptiles into ecosystems have rapidly increased. These extinction and colonization dynamics influence functional diversity (the suite of functional traits present within an ecosystem) and the prevalence of ecosystem services that humans depend upon such as pest control, pollination, and seed dispersal. The extent to which reptile functional diversity–and by extension, ecosystem services–have changed over the Quaternary remains poorly understood. Here, I quantify function diversity change in Caribbean reptiles, a species-rich insular fauna. Traits such as body size, diet, and habitat affinity are used to partition species into functional entities (FEs): groups of species with similar traits that are expected to provide similar ecosystem services. Archaeological and paleontological data are used to reconstruct ecological communities through time for seventeen islands, with an emphasis on ancient, native extant, and modern (native extant plus introduced) faunal assemblages. I find that several key FEs are lost due to extinction. Extinction caused the most significant losses of functional diversity on small islands, which lost up to 67% of their native FEs. On the other hand, functional redundancy on large islands served as a buffer to major functional diversity loss in the past. Species introductions not only increase functional diversity, but they shift the functional space of reptile assemblages, meaning that introduced species exhibit novel functional trait combinations not found in extinct or native taxa. These shifts in functional diversity leave many native FEs and the communities that they support vulnerable to additional biodiversity loss. I also identify places that have retained a significant amount of native functional diversity, indicating that the anthropogenic history of an island contributes to present-day conservation prospects. This research provides critical data on long-term functional diversity change in a taxonomic group whose contributions to ecosystem function are understudied and often undervalued, and provides a path forward for conservation management.

Ecosystem Resilience In The Face Of A Changing World: Preliminary Results from Jonkershoek

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Global projections surrounding ecosystem vulnerability and biodiversity loss have heightened in recent decades due to climate change and land use. Mediterranean Type Ecosystems (MTEs) are projected to be highly vulnerable to global change due to changes in plant available moisture, changing fire regimes, and introduced species. Jonkershoek Nature Reserve, an MTE in Western Cape South Africa has undergone environmental monitoring since the early 20th century, but is bereft of insights on millennial-scale vegetation change, climate, fire, and herbivory, which have significantly shaped the landscape. Long-term data spanning the period before anthropogenic climate change and intensive land use are needed to assess these impacts and inform management and restoration.

A 104 cm wetland core, from a Fynbos-Forest Ecotone was analyzed to reconstruct the vegetation, herbivory, and fire history. Over the past 5000 years, forest taxa did not show a significant increase, providing support for the idea that fynbos is resilient to forest encroachment. This may be attributed to fire-vegetation feedback, which excludes fire-sensitive forest taxa from fynbos areas. The high rainfall at this site may further buffer fynbos resilience.

Results show that prior to 345 BP, grasses and dry-adapted species had dominated the fynbos vegetation, with minimal fires and less grazing. The high rainfall at this site may buffer fynbos resilience. Post-colonial anthropogenic influence since the 17th century is noticeable because of the introduction of alien species and increased herbivory. Such processes may have affected the landscape at community level, resulting in a corresponding change in the fire regime. Extreme fire events are evident in the core from 220 BP. A decline in Poaceae pollen is concurrent with an increase in Restionaceae and Ericaceae pollen types.

Long-term monitoring of landscapes at millennial scale offers an in-depth understanding and interpretation of contemporary changes for setting sounder restoration and management objectives. Despite biome scale vegetation resilience, strong anthropogenic influence and change in fire regimes in recent centuries is an aberration in terms of the longer history at the site and can be attributed to increased fuel load due to fire suppression. Preserving the ecosystem while revising the burn policy is suggested.

Relevant conservation metrics linking past and future biodiversity change

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Knowledge on past biodiversity change is essential to anticipate and manage the responses of species and ecosystems to ongoing global change. However, we face the challenge to develop harmonized indicators that can capture over time relevant dynamics for integrating them in widely used conservation metrics, including IUCN Red List, Living Planet Index or the Essential Biodiversity Variables. Here I will discuss the prospects and challenges to develop such metrics linking Quaternary and Anthropocene temporal realms. I will present several examples for visualizing how the integration of paleo-records and contemporary data provides novel venues for bringing Quaternary disciplines into the conservation arena with a special emphasis on metrics relevant for genetic diversity, species abundance and functional diversity.

One more way for Palaeoecology to contribute to conservation biology; discovering the endangered hidden species, the case of the liverwort Riella (Riellaceae)

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Palaeoecology can contribute to conservation biology mainly through helping (i) to understand biological invasions, (ii) to reconstruct biodiversity and dynamic equilibrium between extinction, migration, and persistence, and (iii) to detect and delimit the glacial and interglacial refugia as conservation targets. The ecological and palaeoecological literature is becoming increasingly rich in examples illustrating one of the above cases. In this study we present another potential of palaeoecology serving to conservation biology which is underestimated by both conservationists and palaeoecologists. The basic idea is that in some biogeographical territories in which the biodiversity is not still poorly documented, (e.g. biodiversity hotspots), high-quality palaeoecological records can reveal the presence of 'hidden taxa' which have not been recorded in modern fauna and flora. We present the specific case of the liverwort genus of *Riella*(Riellaceae) in the lake and wetland environments of the semi-arid regions of Southwest Asia. Members of this family are commonly present in Quaternary palaeoecological records but almost absent in modern flora of the region. In the face of the ongoing anthropogenic climate change, several hidden species of this genus are seriously endangered and have to be urgently protected within their natural habitats. Our palaeoecological findings can contribute to pinpointing the most promising sites for botanical exploration and for conservation of the last living species of the genus in the drylands of Southwest Asia.

Changes in plant diversity and vegetation structure based on REVEALS reconstructed vegetation of Europe during the Holocene

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Land use and land-cover change are the greatest drivers in biodiversity loss and thereby loss of ecosystem functions. [M1] To improve the understanding of current processes in diversity and its impact on ecosystem functions and global environmental changes, knowledge of past interactions between diversity, vegetation structure and land use is needed. We use here the 3rd generation of REVEALS vegetation estimates (Serge et al. (unpub.) at European-wide scale based on large pollen dataset (1606 sites) to explore the vegetation structure and diversity change during the Holocene. Space-time constrained clustering of the REVEALS estimates of Serge et al. (unpub.) revealed 6 dominant vegetation types: (1) Mediterranean vegetation, (2) open (anthropogenic)[lm2] vegetation, (3) *Abies-Fagus* forest, (4) broadleaved mixed forest, (5) needle-leaved mixed forest, (6) cold pioneer vegetation. Changes in location, size, floristic composition and diversity within the vegetation types characterized 4 phased during the Holocene. α-Diversity as the floristic richness, richness of abundant species, and evenness was explored, as well as β-diversity defined as the variation between grid cells of the same vegetation type. Additionally, temporal turnover within vegetation type was explored. Generally, open vegetation types (VT1 and VT2) showed higher β diversity and lower evenness than forests. The first phase was a pioneer phase until 9500 calBP with cold pioneer vegetation and the second phase was widely distributed broadleaved mixed forest until 5500 calBP. Both phases have low human impact resulting in relatively low β-diversity but high evenness. Afterward, extensive land use started in the third phase resulting in a change towards open anthropogenic vegetation, *Abies-Fagus* forest and mixed needle-leaved forest. From 1700 calBP on, land use intensified, marked by the expansion of open (anthropogenic) vegetation and increasing abundance of *Cerealia* and anthropogenic indicators. Evenness dropped, as well as β-diversity. The forest vegetation types change their composition towards open anthropogenic vegetation. In general, vegetation composition harmonizes, evenness drops extremely, and open anthropogenic vegetation dominates throughout Europe in most recent time windows.

The paleogeographic vision. Unveiling the ghost of time to assess ecosystems and develop conservation and restoration actions.

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The current anthropogenic Global Change has pushed Earth into an environmental emergency. Increasing our knowledge of how the Earth's biodiversity responds is an urgent and challenging task. Integrating paleoecology into ecological research will increase our understanding of long-time ecological processes relevant to biodiversity and conservation. In this regard, islands are an open lab to exemplify what driving forces have shaped island communities and their biodiversity. Here we have studied terrestrial and aquatic biota of lake sedimentary records from the Azores archipelago. We show how the human colonisation of the archipelago overtakes the impact of natural variability (climate and volcanoes) on local and regional biodiversity. However, site-specific features (geography, lake and catchment morphometry) result in different responses, including ecosystem resilience and recovery after environmental fluctuations and perturbations. We discuss the main problems and possible solutions (e.g., machine learning approach) for using paleoecological records to assess biodiversity. We also recognise the difficulty of applying widespread conservation and restoration policies due to site idiosyncrasies. For instance, the existence of ecological tipping points could compromise the effectiveness of conservation and restoration policies by incurring disproportionate costs or damaging the current socioeconomic system.

Contribution of the Quaternary sciences to find the balance between action and laissez-faire in Ecology

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Quaternary Sciences can provide empirical data prefigurating realistic future ecosystem changes. This is particularly helpful for managers looking at finding a suitable balance between implementing restoration actions and "laissez-faire", in the light of the climatic projections.

Here we present a case study of Historical Ecology applied to a Mediterranean wetland (Bagliettu peatbog, Corsica Island): 1) to reconstruct 3900 years of insect and plant ecological successions and changing habitats, 2) to identify respective and cumulative roles of past disturbances (i.e. geomorphic evolution, climate changes, land use) in the shaping of ecological communities, and 3) to discuss conservation status in the light of the long-term dynamics. This type of peat-bog within the Mediterranean bioclimate is very rare and thus deserves protection. Our findings reveal that this peat-bog has thrived several millennia of evolution with relative resilience to centennial-scale aridity events. However, reduced wetland connection due to a multimillennial-long trend of river incision play a major role in the recent degradation of wetland, unlikely reversible at our human scale. With the added effects of anthropogenic disturbance, which has been identified as increasing in the fossil record, the disappearance of the ecosystem might occur independently of changes in the precipitation regime even if reclamation actions are initiated.

Another peat-bog located in the same river valley (Valdu), is probably a more valuable target for conservation. Indeed, a closer position to the aquifer makes this wetland comparable to a young stage of the geomorphic evolution of Bagliettu, and thus more suitable to achieve goals of long-term conservation.

Predicting extinction risk from future climate change with the paleorecord

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Accurately predicting biodiversity loss from climate change requires a detailed understanding of the ecological characteristics that make some species more susceptible to declines and extinction. However, the ecological attributes that increase extinction risk from climate change are poorly resolved. This is because ecological responses to climate change are complex and hard to quantify correlatively. I will show how biological data from the late Quaternary can be combined with simulation models to disentangle complex interactions between ecological traits, climate and other threats. I will then show how this is enabling species responses to climate change to be contextualised and integrated into future biodiversity projections and policy. By providing a more complete understanding of the ecological mechanisms that regulate species' responses to climate change, the paleorecord can help identify and conserve the species that are most vulnerable to future climate change.

Quaternary marine palaeoecology, molecular biology and geochemistry; challenging the shifting baseline syndrome

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The palaeoecological and geochemical interpretation of Quaternary marine sequences has hitherto been dominated by the requirement for physical environmental proxies for palaeoclimatic and sea level reconstructions. Yet these sequences, and other marine biotic archives, such as coral, coralline algae, molluscan shell, fish and marine mammal bone, also contain a wealth of information on past biodiversity and ecosystem functioning. Marine sedimentary sequences are usually investigated for selected groups e.g. diatoms, and/or groups that represent significant geochemical carriers e.g. foraminifera, and only very rarely is the totality of the preserved fossil assemblage analysed. When well-dated these data can provide insights into the richness of past ecosystems, the role of keystone species, and provide ecological baselines that challenge the “shifting baseline” syndrome. Even these more comprehensive analyses, however, can only capture a fraction of former marine ecosystems because of taphonomic loss. Novel approaches to marine ecosystem reconstruction, including sedimentary environmental DNA (eDNA) and compound specific stable isotope geochemistry, are now able to provide insights into the total biodiversity of former marine ecosystems, and ecosystem functioning, respectively. Combined with classical palaeoecological approaches, these techniques together provide powerful integrative tools for the reconstruction of marine ecological baselines. Such reconstructions provide evidence-based targets for marine conservation biology and an informed basis for the rewilding of the oceans.

Linking paleoecology, archaeology and history; an innovating approach to investigate how human activities have modified the natural forest trajectories in the Southern French Prealps

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Reconstructing the forest trajectories in Quaternary time-scale and disentangling the impact of human activities from natural forcings on those trajectories is essential for conservation and effective management of the forest heritage. The knowledge of the recent ecological history of forests provides a means of apprehending their functioning and designing conservation and restoration strategies for their future, facing the ongoing global change. A detailed reconstruction of forest dynamics can be achieved by cross-correlating historical and archaeological data with palynological, archaeo- and pedo-anthracological data. The first difficulty is to find chronological matches between the information provided by different archives treated in different disciplines. Another difficulty is the substantial quantitative and qualitative disparity of the available sources. Nevertheless, we hypothesize that i) cross-referencing of these different sources with complementary spatio-temporal resolutions, can improve our understanding of the history of mountain socio-ecosystems and ii) that pedo-anthracology can make a significant contribution. In this study, we show the interest of comparing and contrasting these different natural and historical archives. To test our hypothesis, we take as 'system model', three mountain forest ecosystems in the southern French Pre-Alps (Lauzet-sur-Ubaye, Prads-Haute-Bléone and Thorame-Basse) and apply a systematic pedoanthracological investigation along several altitudinal transects. For the first site, both historical and palaeoecological data were available, for the second site, only historical data were accessible and for the third site, historical and archaeological data were both available. The first results and radiocarbon dates obtained confirm the interest and potential of interdisciplinarity in the reconstruction of past forest dynamics. This has made possible to highlight the significant role of agro-sylvo-pastoral practices in modulating the spatial distribution of the forest for Le Lauzet-Ubaye and Prads-Haute-Bléone. Furthermore, for the latter sites, the forest composition would not have been deeply affected by pastoral activities. This is yet to be determined for the Thorame-Basse site, which has been the subject of numerous reforestation campaigns in the last centuries, with the introduction of non-native species. Our results will help to better consider the human disturbance on forest functioning, when designing conservation and management strategies and have applications in species distribution modelling (SDM).

Reconstructed lake food webs reveal ecosystem-level responses to late Holocene climate and human-induced changes across the Azores Archipelago

***Dr. Miguel Matias* [1], *Dr. Manuel Mendoza* [1], *Prof. Vítor Gonçalves* [2], *Dr. Sergi Pla-Rabes* [3], *Prof. Roberto Bao* [4], *Dr. Martin Souto* [2], *Dr. Armand Hernandez* [4], *Prof. Alberto Sáez* [5], *Dr. Santiago Giralt* [6], *Dr. Pedro Raposeiro* [2]**

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The UN Decade on Ecosystem Restoration aims to prevent, halt, and reverse the degradation of aquatic ecosystems across the planet. Addressing this challenge requires a comprehensive understanding of how ecosystems have changed over time to better support decisions on identifying, prioritizing, and optimizing restoration actions. Lake ecosystems are well-known "sentinels of change", providing valuable insight[AHH1] s into past and ongoing environmental changes. Multiproxy palaeolimnological reconstructions allow identifying long-term changes during the Late Holocene in the condition of lakes and correlate changing conditions to environmental and climate drivers over a range of temporal scales. Palaeoecological data is increasingly used to set baselines of changes in biodiversity, although such baselines are often limited to population or community-level changes in aquatic ecosystems. Food-webs represent energy flows between species or groups of species and provides a framework for understanding species' roles within ecosystems and the mechanisms through which biodiversity influences ecosystem function. Recent developments in food-web ecology have revealed that functional traits (i.e., ecologically meaningful features of species measurable at individual level) are effective predictors of trophic interactions and can be used to approximate the overall structure of aquatic food-webs. This study uses lake sediments to reconstruct past environments and aquatic trophic structures (i.e., paleo food-webs) across five different lakes in the Azores archipelago (North Atlantic Ocean). Recent investigations of Azorean sediment records have shown substantial reorganizations in community composition (or regime shifts) over the last millennia because of archipelago-level climatic changes, catchment-level vegetation changes and lake-level fish introductions. Ecosystem regime shifts in Azorean lakes vary in speed and magnitude as a function of the environmental and anthropogenic drivers leading to a redistribution of species richness and abundance across trophic levels. Incorporating ecosystem-level baselines in global change research provides a novel perspective supporting future conservation and restoration actions.

What can we learn from changes in pollen type diversity?

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The ongoing biodiversity crises calls for a better understanding of past changes in floristic diversity, with a need for baselines beyond monitoring periods. Pollen analysis is probably the best suited technique available to provide such information, while it comes with several challenges. Pollen grains can rarely be identified to plant species or even genus level, but still pollen type richness in samples increases following a latitudinal gradient from the boreal forest zone to the Mediterranean. Across such large regions changes in pollen type diversity correspond to changes in plant richness suggesting that pollen type richness may be a good indicator of past changes in plant richness. Postglacial pollen diagrams from western Europe document strong shifts in pollen type richness over the postglacial, however, these patterns strongly correlate with the proportion of arboreal pollen in the samples. Surely, open vegetation types contain more plant species compared to dense temperate forests, but temperate trees also produce much more pollen than most herbaceous plants in western Europe. Therefore, it remains uncertain how to interpret these changes. Few modern and simulation studies have recently investigated the relationship between plant diversity and pollen type diversity. Based on these insights we explore past trends in pollen type richness in connection to climate induced shifts in forest cover and manmade de- and afforestation. A focus will be on pollen data from Switzerland and the high-resolution analysis from Eversener See in Northern Germany. We will explore if the onset of the current biodiversity crises and decline in floristic diversity is documented in existing diagrams.

It’s time to widen our gaze: how a simplified world view blinds our attempts to understand the past, present and future

Prof. Michael Fletcher [1]

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Contemporary landscapes are the product of past processes. A failure to recognise or understand these past processes limits our capacity to manage environments sustainably. While Quaternary science has a long history of attempting to understand how people have modified the planet, our science and hypothesis generation are often framed through a dehumanising lens. This is particularly the case in the global south and other more recently European colonised landscapes in which Indigenous and local peoples have lived in and managed for millennia. In these places, the baseline assumption is that landscapes are the product of natural (i.e. non-human) processes. Within this paradigm, attempts to assert human agency in accounting for landscape change in long occupied landscapes using the palaeo-record suffer a disproportionate and inappropriate burden of proof. This burden requires either unequivocal evidence of human agency or the elimination of other potential processes, leaving humans as the most parsimonious explanation. The former is near impossible in palaeo-science, while the latter is most often achieved by identifying trends that are anomalous to what would be expected “naturally”. This framing denies the fact that people have and continue to leverage natural processes in their engagements with the world.

In this talk, I will unpack how dehumanising long-occupied landscapes robs us of the ability to truly understand the past and how this results in inappropriate management solutions to our environmental challenges. I argue that engaging with people who view the word differently, such as Indigenous and local peoples, can result in more appropriate epistemological frameworks that allow a more successful approximation of the past, leading to better outcomes for management approaches. It is my contention that this is one of the greatest contributions that Quaternary sciences can make to the future.

Integrating extant and Quaternary biodiversity assessment through shared priority metrics: palynological data as an archive of phylogenetic diversity

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Quantifying past biodiversity change and understanding its drivers are key contributions that palaeoecologists can make to inform environmental and conservation policy. Integration of neo- and palaeo-ecological datasets requires the use of shared metrics, however, meaning that we need to focus our attention on those variables being used to assess and manage biodiversity in modern systems, such as Essential Biodiversity Variables (EBVs). While taxonomic diversity – the number of species and their relative abundances in an assemblage – is included in the EBVs and is readily calculated from palaeoecological datasets, there is an increasing awareness that this metric only captures a portion of the information needed to understand biodiversity change and make informed conservation decisions. Phylogenetic diversity (PD) incorporates information on the amount of evolutionary history contained in an assemblage of taxa, and can therefore provide a more detailed assessment of biodiversity gains and losses through time and space, and their underlying causes and consequences. To date, however, PD has been underexplored by palaeoecologists, and it is not currently known how well variations in vegetation PD across broad spatial scales are captured by palynological assemblage data. Here, I compare estimates of PD from North American surface palynological samples and vegetation plots, and show that palynological data represent the overall variations in vegetation PD well. This suggests that historic variations in PD, and their relationship to climatic, environmental, and human land use changes, should be recoverable from (sub)fossil palynological archives. Utilising ecologically-relevant metrics such as EBVs should be a priority to increase the relevance of palaeoecological research for assessing current and future biodiversity change.

Session 142:
Palaeoecology and restoration ecology

The value of long-term history of small and fragmented old-growth forests for restoration ecology

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Primary and old-growth forests are of great value for sustainable forest management and restoration as they offer templates to develop close-to-nature forest management practices aimed at emulating natural processes and features in second-growth forests. In Europe, primary and old-growth forests are very rare, generally small, fragmented, and less abundant (< 3% of the total forest area) than on other continents. Current fragments are arguably remnants of formerly larger extents of primary and old-growth forests, which have been increasingly embedded in humanized mosaic landscapes and are still often threatened along fragment edges by land-use activities (e.g. logging) and anthropogenic disturbances (e.g. fire ignitions). However, the legacy effects arising from complex interactions between natural and human disturbances that eventually led to their fragmentation are often weakly constrained.

Here, we used stand-scale paleoecology, an assessment of contemporary forest structure, and dendrochronological data from the edge of the Biogradska Gora old-growth forest (Dinaric Alps, Montenegro), one of the largest in Europe, to provide new insights into the long-term dynamics of these fragmented ecosystems.

The records support the notion that historical land-use pressure (cereal crop cultivation, cattle herding, fires) reduced the extent of old-growth forests. Conversely, land abandonment in the mid-14th century (approximately at the time of the Black Death pandemic) as well as the formal protection since the late 19th century prevented intensive land use, and has strongly reduced biomass burned in recent times. These land-use changes allowed for the expansion and persistence of forest stands in the buffer zone, which may offer suitable habitat for the expansion of disturbance-sensitive old-growth stands. Thus, in addition to unfolding the historical legacies that led to the fragmentation of primary and old-growth forests, our study also shows that the protection of buffer zones is of importance to promote native forests.

Past, present and future perspectives of European megafauna and their ecological impacts

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Severe, size-biased defaunation has degraded European megafauna assemblage after the arrival of *Homo sapiens* during the late Pleistocene and the encroachment of human modern society in ecosystems thereafter. Thus, there is a call for ambitious megafauna-community restoration policies to rewire pivotal dynamics of ecosystems resilience and of biodiversity structuring. However, managing human-megafauna coexistence in the hybrid wild-anthropic cultural landscapes of Europe is non-trivial, notably with such landscapes rapidly transforming under the global environmental changes of the XXI Century. We used fossil records and ecological traits to estimate, mainly via habitat modelling, European megafauna biogeography at a time prior the arrival of *Homo sapiens* in Europe, the Last Interglacial (cc. 127,000 years ago). We described how megafauna extinctions and consequent environmental degradation affect present ecosystems viability compared to such 'natural baseline'. We explored how megafauna assemblages were degraded by humans throughout history, notably comparing the role of overhunting vs. habitat fragmentation. Furthermore, we estimated future megafauna distribution and population densities under scenarios of climate and land-use changes, in combination with different rewilding strategies, to find best trade-offs between the need to restore ecological dynamics and the risk for human livelihoods. European megafauna community biomass has dropped by 93.8% from the Last Interglacial to the present. Functional diversity has dropped by 90.8% for herbivores and 83.3% for carnivores. Vegetation consumption has dropped by 88.3% and meat consumption by 68.5%. As a result, the structure of present ecosystems strongly deviates from the evolutionary norm, notably due to decreased functional heterogeneity. While during the Pleistocene megafauna extinctions were mainly driven by overhunting, the spreading of farmlands in Europe from the Neolithic culture have added an equal threat to megafauna viability in the form of habitat fragmentation, which effects skyrocketed during the last 1000 years. Restoring megafauna-mediated ecological processes in line with the ecosystems' evolutionary norm is possible via reintroductions and by letting megafauna expand their current distribution, but at the cost of a very high potential for conflict. Alternative rewilding implementations, such as controlling population densities via culling, may be more pragmatically approaches in the light of human-megafauna coexistence potential in the Anthropocene.

A multi-proxy reconstruction of Holocene vegetation and treeline dynamics in Central Switzerland

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Anthropogenic climate change increasingly affects life on Earth. Human societies are impacted by rising temperatures, droughts, fires and floods, which also affect plants, creating new ecosystem challenges. In the Alps, the future temperature rise is projected to be almost twice as high as on the global average, which will lead to severe changes in alpine ecosystems and associated services. Palaeoecological archives such as alpine lake sediments can be used to reconstruct past vegetation dynamics. The rapid temperature increase of 2-4 °C at the onset of the Holocene is a possible analogue to current climate warming, thus understanding past responses of alpine vegetation to temperature increases may provide new insights in future vegetation trajectories.
We are currently investigating sediment samples from Golzerensee, a mountain lake situated in Central Switzerland on the northern alpine boundary. The lake lies at an elevation of 1.411 m a.s.l., in the transitional zone between the montane and subalpine vegetation belts. Here, we present a multiproxy reconstruction of local to regional vegetation dynamics during the Late Glacial and Holocene at Golzerensee, based on pollen, macrofossil and charcoal analyses. Emphasis is placed on vegetation responses to climatic changes such as the Younger Dryas cold period or the rapid warming at the beginning of the Holocene, as well as the effects of human land use on vegetation. Specifically, we are interested in the timing of local forest establishment and the drivers of mountain forest compositional change under rapidly warming climate. The ultimate goal of this study is to assess the response of mountain vegetation in the Swiss Alps to future global change and identify palaeo-based restoration strategies that will help maintaining Alpine biodiversity and ecosystem services. For instance forests growing under warmer-than-today summer conditions during the Holocene Thermal Maximum ca. 10.000-5.000 years ago may provide useful guidelines to support future forest diversity and provisioning services.

Climatic and anthropogenic impacts on Holocene vegetation dynamics in Eastern Switzerland.

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Mountain vegetation is particularly affected by climate change. Despite the growth of monitoring programs assessing the impacts of current global change on alpine ecosystems, there is still an insufficient use of long-term studies in conservation biology to understand ecosystem responses on long timescales. Paleoecology has made important contributions to the reconstruction of vegetation responses to past environmental and societal changes based on multiproxy studies including biotic proxies such as pollen and plant macrofossils preserved in lake sediments.

The last climate change of a similar magnitude and rate as projected for this century occurred during the transition between the last Ice Age and the Holocene interglacial (ca. 11,700 years ago), when temperatures rapidly increased by 2-4 °C within less than a century. Additionally, mountain vegetation in the Alps has been affected by millennia of human land use. Understanding the response of vegetation to rapid temperature increase and human impact is a fundamental prerequisite to produce accurate and reliable predictions of future mountain vegetation and mitigate climate change impacts.

We present our multiproxy study of a sedimentary record from Lai da Vons (1991 m a.s.l.), an alpine lake situated at the treeline ecotone in Eastern Switzerland. Our results based on geochemical analysis (XRF), pollen, charcoal, and high-resolution macrofossil analyses, reveal that the first trees already established locally 13,500 years ago, in response to rising temperatures. Closed forests dominated by conifers like *Pinus cembra*and *Larix decidua* expanded after the Early Holocene warming. From 9,500 years cal. BP onwards, when summer temperatures were warmer than today and moisture availability comparable, *Picea abies* and *Abies alba* spread. During the past 6,500 years, increasing human impact as indicated by several cultural indicators led to a progressive opening of the landscape and a diversification of local species composition in the open lands, but impoverished monospecific forests. This development was interrupted during the past ca. 70 years by spontaneous afforestation in response to land use changes related to globalization. We conclude that restoring the original diverse forests in combination with low-intensity pastoralism will be key to preserve future plant species diversity and mitigate adverse climate change effects.

Holocene REVEALS pollen-based land-cover reconstructions in Europe - exploring dynamics in diversity and resilience over time

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Land use and land-cover changes are ranked as the greatest driver of declines in nature and biodiversity. Thereby it is crucial to enhance our understanding of natural landscape interactions and anthropogenic-induced changes to evaluate the effects of future climate and land-use changes on European ecosystems, landscapes and biodiversity.

As part of the Terranova project (H2020-msca-itn-2018), we present here the "third generation" of pollen-based estimates of plant cover in Europe using the REVEALS (Regional Estimates of Vegetation Abundance from Large Sites) model at a spatial resolution of 1°x1° (ca. 100 km x 100 km) for consecutive time windows over the last 11.7 ka cal BP. This new reconstruction improves the spatial cover of the last generations of REVEALS reconstructions with a large number of additional pollen records in particular from the Mediterranean area. We discuss methodological issues using alternative datasets of relative pollen productivities (RPPs), one of the key input parameters. After validation with the modern vegetation dataset, the RPP-means dataset 1 (31 taxa) was found to be the most suitable for Europe.

This new dataset provides unique possibilities to explore spatial-temporal changes in past land-cover and biodiversity over long time periods. The aims are (i) to recognize vegetation types during the Holocene and its movements and shifts from the last glacial maximum to the present time (ii) to derive past diversity indices (α and β-diversities) within each of the biogeographic regions and (iii) to identify the species contributing to the groups and the β-diversity.

According to the identification of six vegetation types during the Holocene (Röhm et al., in prep), REVEALS estimates are explored. The aim is to identify resilient stable states and transitions in Europe and to which environmental variables they are mainly related. We bring to light the effect of homogenization of vegetation in the properties of ecosystems, like the loss of ability to absorb environmental changes, that negatively affect resilience in recent times.

Old flames: the relationship between cultural burning and fire histories on Gunaikurnai Country, Australia

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The *Black Summer* 2019–20 fires burned nearly half of the forest estate across Gunaikurnai Country (East Gippsland), Victoria, Australia. How these catastrophic fires were caused — by climate change and/or land management — has been the subject of political and academic debates. These debates have emphasised the reinstitution of Australian Aboriginal cultural burning to help mitigate such catastrophic bushfires. Australian Aboriginals and Torres Strait Islanders have used cultural burning for millennia (amongst other purposes) to reduce fuel levels and the risk of high-intensity bushfires, akin to *Black Summer* fires. While the call to reinstate cultural burning is based on reservoirs of traditional knowledge and practice, there is limited empirical data on pre-British Invasion vegetation and fire dynamics. This data gap represents a barrier between this fire approach becoming policy and practice in a managed landscape. Changes in pre- to post-Invasion vegetation (i.e., fuel) and fire in Eucalypt-forest in the Point Hicks area, East Gippsland, Australia are investigated using palaeoecology and dendrochronology of fire-sensitive trees. I will analyse the fossil charcoal and pollen in the sediments of two proximal wetlands which are critically located in the *Black Summer* bushfire zone. Radiometric dating, geochemistry, and Fourier Transformed Infrared (FTIR) Spectroscopy will be used to anchor changes in time, understand erosion shifts and catchment dynamics, and infer fire temperatures from charcoal, respectively. To enhance the fire history reconstruction, I will use dendrochronology to investigate the influence of past fires on fire-sensitive pines (*Callitris rhomboidea*) stand dynamics. Here, I will present key findings from this Masters research to highlight the use of palaeoecology in ecosystems management.

Ecosystem response to climate change and human impact in South Carpathian alpine lakes: can we define restoration targets?

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Mountain lakes in the South Carpathians have undergone rapid ecological changes due to intensive mountain grazing, warming and consequent trophic level increase over the last century. In this study multi-proxy analyses of short sediment cores from the Retezat, Pareng and Fagaras Mountains were used to determine preindustrial reference conditions and reconstruct the rate of ecosystems change in response to stressors.

By the high-resolution (2 cm) study of 4 alpine lake gravity cores covering the last 250 years, our aim was to identify early warning signals of critical transitions and define regional safe and just operating space (RSJOS).

Multi-proxy analyses included Pb210/Cs137 dating, chironomid, diatom, pollen, cladocera, SPDU (chlorophyll-derivatives), LOI, TOC, TN, C/N ratio and geochemical analyses are in progress on Lake Latoritei (1530 m), Lake Belea (2034 m), Lake Ana (1940 m) and Lake Peleaga (2122 m).

The results of the ecological regulation analysis showed that deep, high-mountain lakes were transformed and entered the cautious status between ~1926-1950. Before the turnover date, the reference state was characterised by higher abundance of Micropsectra insignilobus-type and Heterotrissocladius marcidus-type in their chironomid fauna. All three deep lakes were characterised by a move from an equal share of collector-gatherer and collector-filterer feeding guilds towards collector-filterer dominance.

Turnover for several ecosystem components was detected in the lower lying, shallow Lake Latoritei around 1850. The preindustrial reference state was characterised by high abundance of Tanytarsus mendax-type. In this lake the transition of feeding guilds reflected the shallowing and submerged aquatic expansion via the prevailing dominance of shredders and collector-gatherers.

Multivariate data analyses from Belea and Latoritei furthermore suggest that changes in the chironomid fauna can be best explained by the ongoing increase in the summer mean temperatures, which was the dominant driver, followed by human disturbance. We expect a similar trend in the case of Lake Peleaga and Lake Ana.

The common feature of the four pollen records was the late 18th century (1780-1795) deforestation in the sub-alpine spruce forest zone, followed by intensified forest cover loss between AD 1950 and 1980.

Keywords: RSJOS analysis, chironomids, human impact, climate change, mountain lakes

Landscape history in the Central highlands of Madagascar: its implications for the conservation and management of the open and mosaic ecosystems

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Open and mosaic ecosystems are often classified as degraded or secondary forests, particularly in the tropic where climatic conditions are favorable for forest development. This assumption is associated with the current high deforestation rate and other human-made activities observed in this region promoting reforestation projects. This is the case in the Central Highlands of Madagascar, which is narratively thought to be forested but currently dominated by open grassland ecosystem. However, the origin and nature of the landscape and its drivers of change are not clear and scientific debates are still ongoing either the region's grassland is natural or anthropogenic driven. Distinguishing ancient from derived open ecosystems has important management and conservation implications. Here, we aim to understand the environmental history in the Central Highlands of Madagascar before and after human settlement (ca. 2 cal. ka BP) to provide guidance for the landscape restoration and management. We used pollen, stable carbon isotopes, charcoal, and dung fungal spores from a core retrieved in Lake Dangovavy covering the mid-Holocene. Results revealed that at least since ca. 6.3 cal. ka BP, vegetation surrounding the lake has been dominated by a mosaic of open grasslands and ericoid scrubland compressing forest patches of variable elevation. Before human settlement (6.3–2 cal. ka BP), the mosaic landscape was more resilient despite low to moderate variation of fire and herbivory activities recorded in the area. After human settlement, vegetation remained stable between 2 and 1.1 cal. ka BP associated with low fire and herbivory activities. However, it shifted to a more open grassland dominated during the last 1100 years associated with high fire frequency and herbivory activities. Massive declines in ericoid shrubland and forest patches were recorded in the area, and it was associated with increasing human impact and probably aridification in the region. These results indicate the natural presence of open and mosaic ecosystems in the Central Highlands, which predate human settlement and are worthy of conservation. These inform restoration focus on taxa linked to forest patches while managing fire regimes to a moderate level for maintaining ancient open ecosystems.

Applications of palaeoecology to ecosystem restoration and management in the Mediterranean region

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In the past few years, increasing attention has been paid to the application of palaeoecological records to guide ecosystem conservation, restoration, and management. In this communication, I will summarise several recent case studies from southern Europe drawing on the applied use of palaeoecological data to different ecological questions. Specifically, I will focus on the protection and restoration of mires and relict temperate tree species threatened by increasing densities of wild herbivores, on the natural range of variability of fire disturbance affecting pinewoods and the consequences of altering such fire regime, and on assessing the composition and structure of the 'natural' vegetation. The results highlight the potential of palaeoecological investigations on the relatively recent past to guide present and future conservation and restoration efforts in areas with a long and intense history of land use like the Mediterranean region.

Mapping the Moor: Palaeoenvironmental reconstructions to inform conservation management at Hatfield Moors, South Yorkshire, UK

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Palaeoenvironmental datasets have considerable potential for informing present-day conservation management, but their application is often limited by their relatively low spatial and temporal resolution. Recently developed algebraic models of pollen dispersal and deposition can translate point-source pollen data from multiple sites into quantified reconstructions of past land-cover. The Multiple Scenario Approach (MSA) provides a framework for applying these models which generates spatially explicit land-cover reconstructions for identified timeslices. The temporal resolution of palaeoenvironmental sequences is also improving through application of techniques such as Bayesian modelling of chronological information.

Applications of the MSA to date have focused on reconstruction of archaeological landscapes at a regional scale. These reconstructions have a relatively coarse spatial resolution due to the dispersed nature of pollen sites in these landscapes. Another limitation has been a lack of contemporary input datasets (e.g. grids of topography and substrate), which are used to constrain placement of vegetation communities to produce hypothetical maps of land-cover for which pollen assemblages are then simulated and compared with empirical pollen data. Whilst the MSA reconstructions undertaken to date have produced a broad-scale picture of land-cover change over time, they have not provided the detailed information at a fine spatial scale that is needed by conservation managers.

Building on previous work at Hatfield Moors, South Yorkshire, UK which produced detailed reconstructions of pre-peat topography and mire extent from its mid-Holocene origins to present, we apply the MSA to land-cover reconstruction at this site. Hatfield is part of the Humberhead Peatlands National Nature Reserve, the largest area of lowland raised bog in Britain. These peatlands have been heavily impacted by drainage and industrial peat extraction, primarily since the 17^{th} century, and current restoration efforts aim to manage vegetation and water levels in an attempt to reinstate the vital ecosystem services provided by healthy, functioning peatlands. This paper presents the results of palaeoenvironmental modelling using the MSA to establish the processes of peat development and ecological succession during the mid-Holocene and inform effective conservation management of the site.

How paleoecology can support peatland restoration

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Ecosystem management and restoration are currently challenged by rapid climate change and rising anthropogenic pressure. Many ecosystems in various geographical locations may undergo critical transitions due to rapidly changing climate. Often, management techniques used in the past are no more efficient and need modifications or a different course of action. Palaeoecological research can provide crucial information on long-term ecological transitions, disturbance events, and the response of organisms (e.g., plants, microorganisms) to environmental changes and human impact. This can then be translated to ecological modelling and is valuable for biological conservation, restoration and management. Among ecosystems that require proper management policies are peatlands, one of the essential carbon stocks worldwide that are significantly affected by global warming and land use changes. The linkages and feedbacks between peatland microbial communities, vegetation composition and hydrological conditions are complex and thus require specific management strategies and monitoring tools. This contribution will present examples of how paleoecology can help define and track past disturbances and ecological transitions, as well as provide suitable management strategies for peatlands. Given examples will include fire disturbance events, effects of peat extraction on peatland hydrological status, and management of peatlands in forest plantations.

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Palaeoecology and Peatland Restoration: Embedding the Practitioners' Perspective

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The persistence of a major research - practice gap prevents palaeoecology from achieving its full potential in supporting restoration ecology. Healthy peatlands contribute to climate resilience and provide a haven for biodiversity; thus, their restoration is a vital endeavour and academic research can provide a robust evidence base to inform restoration. However, the value of palaeoecology for guiding peatland restoration is hindered by a lack of effective science - practice communication. Therefore, this project aims to address the prevailing research - practice gap and increase research impact by developing a process of research - practice collaboration. This case study will focus on three lowland raised bogs under conservation management in the Greater Manchester region, UK. Each site has been subject to direct and indirect anthropogenic disturbance, including peat cutting, drainage for agriculture, and pollution, and have been under conservation management for time periods spanning from recent years to several decades. This study details an approach for early-stage collaboration, specifically focusing on methods for engaging research end-users in key preliminary phases of research design. Early engagement with key project stakeholders is essential for maintaining research relevance to practice, thus, increasing research impact by facilitating the integration of results into practical settings. In this study, a combination of meetings, site visits, surveys, and workshops are used to refine palaeoecological research aims and prioritise research questions in the context of practitioner needs and constraints in peatland restoration practice. In addition to honing the research focus, this process created space for practitioners to offer experiential knowledge regarding the site histories and restoration works. This is essential for ensuring that recommendations made from palaeoecological research are practically feasible and align with practitioner needs. This phase of collaboration will feed into the focus and methodology of the palaeoecological research. It will be part of an overarching iterative process of practitioner engagement that will continue throughout the project timeline and include the dissemination of research into suitable formats that enable the implementation of the results into restoration targets or management plans.

The future of the past : Potential practial applications of paleoecological findings in ecosystem managements

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Paleoecology can provide long-term ecological information, e.g., ecosystem resilience and natural regeneration, that is difficult to obtain using experiments or observations, but that is critical to develop effective conservation and restoration strategies. It is therefore not surprising to find a statement such as: *"…conservation and restoration can be improved using paleoecology…"* in paleoecology-related publications. However, there is a dearth of examples on how paleo-information can be practically applied in restoration beyond defining pre-human-intervention baselines. Here we present examples of practical applications of paleo-information on ecosystem managements drawn mainly from our work in Indonesia. Paleo-information can help readjusting the goals and targets by providing examples and reflection on what conservation and/or restoration targets are attainable. Information on how natural succession works allows refining the restoration design. Moreover, information on ecosystems' natural resilience and the types of socioeconomic activities that are *"resilience-friendly"* can help addressing related governance and socioeconomic aspects. Paleo-information can also provide invaluable input in policy making and help overcoming public skepticism towards ecosystem conservation and restoration.

Define safe and operating spaces of freshwater lake ecosystems in China

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Global lake ecosystems are under formidable threats in the Anthropocene. Scientists and managers are facing pressing challenges to define a safe operating space for successful lake management in the future. Achieving these goals requires a clear understanding of the nonlinear trajectories of ecosystems' response to changes in multiple interacting drivers at multi-decadal /centurial scales. Based on a synthesis and analysis of paleo-environmental records of more than fifty lakes across China ranging from the 1850s-2010s using multiple statistical methods, we identify the tipping points, magnitude, and frequency, rate of changes, as well as pre-impact conditions of biogeochemical variables of the different lakes. Furthermore, we develop metrics for characterizing the lake ecosystem safety, quantify the safe boundary values and develop regional safe and operating spaces for the lake ecosystem in China. This analysis provides new insights and empirical evidence for identifying the safe operating spaces and restoration targets in degraded aquatic ecosystems, demonstrating that long-term paleo-environmental records can have great potential to inform regional environmental management.

A palaeo-perspective on Insect Armageddon: disentangling the multiple drivers of chironomid diversity

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Anthropogenic changes to the environment are leading to a decrease in global biodiversity, where the insect fauna has been particularly affected with decreases in diversity reported across the globe. The loss of insects is a major problem, as changes to the insect community threaten ecosystem functioning as well as global food security. Most datasets used to assess changes in insect biodiversity are based on decadal-scale ecological monitoring results, and this short time-window does not allow to separate the effects of individual anthropogenic impacts which are simultaneously impacting on our freshwater ecosystems. There is therefore a need for long-term data to better understand the processes that govern insect diversity dynamics. Chironomids are among the most abundant insects in lake ecosystems, are sensitive to environmental change, and as parts of their larval exoskeleton preserve well in lake sediment records, they provide a unique source of information on long-term insect population dynamics. We reconstructed decadal as well as centennial scale changes in the chironomid faunas of a set of lakes in west Norway. Through comparing the chironomid assemblages of surface sediment samples collected during fieldwork in 2019 to findings from 1996 we show that individual lakes show site-specific responses to climate and land-use change. Whilst ca. half of the 20 sampled lakes show only minimal change in their chironomid fauna over the last 23 years, the other lakes show a change in assemblage composition, the arrival of taxa new to the region, or, in one case, the complete disappearance of chironomids from at least part of the lake. The analysis of gravity cores obtained from two of the lakes provides a centennial-scale perspective on the recent chironomid dynamics, showing that assemblage change on longer timescales had a larger amplitude than observed over the last decades. Each lake showed unique site-dependent changes in the chironomid fauna, illustrating that whilst chironomid diversity responds sensitively to external drivers, the expression of the response is non-linear. We conclude that palaeoecological results provide unique insights on insect dynamics and can be of key importance to inform and improve restoration and conservation efforts aimed at protecting vulnerable lake ecosystems.

Tracing the legacy of environmental change and human impact in North Sulawesi, Indonesia, to inform mangrove restoration and management

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Sulawesi‘s mangroves are some of the most floristically diverse globally and have been subject to widespread deforestation and degradation, which has intensified since the 1980s. Governmental and community-based projects have conducted mangrove restoration and rehabilitation activities in Sulawesi, but project outcomes are rarely assessed. It is within this context that the “Comparing Biodiversity and Ecosystem Services of Restored and Natural Mangrove Forests in the Wallacea Regions” (CoReNat) project aims to make evidence-based recommendations to guide future restoration actions throughout Wallacea and Indonesia. CoReNat is a collaboration between Indonesian and UK based research institutions taking an interdisciplinary approach to assess the outcomes of mangrove restoration in North Sulawesi.

To better understand mangrove responses to long-term environmental change and disturbance, we present palaeoecological data (palynology, diatoms, charcoal and spheroidal carbonaceous particles (SCPs)) from three ^{14}C and ^{210}Pb dated cores from two areas in North Sulawesi: 1) a nearly 8,000 year old record from a mangrove lagoon on Mantehage Island, Bunaken National Park; and 2) two Late Holocene high-resolution records from estuarine mangrove stands in Likupang, one taken from a site restored around 2000 CE following the establishment of aquaculture ponds in the 1990s and the other, with no recent history of deforestation, serving as a reference. Combined, the records document substantial changes in mangrove composition in response to long term Holocene climate and sea level changes. Abrupt late Holocene hydrological and vegetation change in the Mantehage record has enabled us to assess mangrove recovery following large-scale disturbance. The non-deforested Likupang site provided no evidence for human impact over the last 200 years, indicating its suitability as a reference site for use by the CoReNat project in their contemporary comparison of natural and restored mangrove stands.

Session 143:
Environmental responses to climatic and human impacts in endangered biodiversity hotspots: past and present for future

Ecological response on environmental change in tropical South America during the late Quaternary

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Detailed records on vegetation and environmental changes during the late Quaternary, based on pollen, charcoal and multivariate data analyses, provide insights on past ecological response on environmental changes. Several examples from South America will be presented. Studies from the Ecuadorian Andes as well as from the lowlands and highlands of Brazil reflect interesting ecological responses to climate change, fire and human impact. Results from continental records from the lowlands and highlands in Brazil as well as marine records show that the response of ecosystems on large scale climate change can be within centuries or decades. Studies from different regions indicate how tropical ecosystems evolved to what they are today. Furthermore they show how sensitive ecosystems are to climate change and how ecosystems responded to natural and anthropogenic environmental changes during the past. This knowledge will help us to understand how ecosystems might change under the ongoing Global Change.

Late Quaternary Araucaria forest and Campos (grasslands) vegetation dynamics inferred from a high-resolution pollen record from southern Brazil

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The forest-grassland vegetation mosaics are very contrasting ecosystems, differing from their structure to functionality. Their controlling factors and their heterogeneity have been very intriguing aspects that fascinate researchers worldwide. To date, few natural remains of these ecosystems still exist, such as the *Araucaria* and Campos region in southern Brazil. Different paleoecological studies account for the vegetation and climate history of the region, documenting changes like shifts between woodlands and grasslands during the last Glacial period (~44000 cal yr BP) until the Late Holocene. However, uncertainty remains about whether the system shifts are rapid or gradual. We reconstruct for the first time in high-resolution (decadal to sub-decadal) the paleoecological history of the *Araucaria* forest-Grassland mosaics in Paraná State during the Holocene to interpret better vegetation shifts and improve our understanding of the dynamics of these subtropical ecosystems. Our data support and complement the paleoecological history of the region, adding details on the systems shifts where gradual vegetation changes are recorded. In addition to the general trend of climatic development, Lagoa Dourada documents for the first time in southern Brazil all three climatic events: the 8.2 ka event, the 4.2 ka event and the Little Ice Age, suggesting that the geographical setting of the lake might have influenced the expression of regional climate, and therefore classifying the study area as a sensitive location in the highlands of Paraná State.

Climate and human effects on a northeastern brazilian Cerrado over the last 800 years

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Understanding vegetation dynamics is essential to interpret long-term ecological changes under different precipitation regimes and land use scenarios. Northeastern Brazil has been subjected to both climatic and anthropic disturbances in recent centuries. In this region, high-resolution pollen reconstructions are challenging due to the semiarid conditions that predominate since the Late Holocene. However, when achievable, they provide insights about landscapes changes in a densely populated region that is rich in both biodiversity and archaeological sites. This study presents a high-resolution record, SAC18 sediment core collected on Cerrado ecotone in the full protected area of Sete Cidades National Park, north of Piauí State. Multiproxy analyses, pollen, charcoal and grain-size showed 800 years of Cerrado species reorganisation during dry and wet intervals. The beginning of the record was marked by a dry episode, with presence of a drought resistant taxon *Curatella* (wild cashew tree) and coincided with the Medieval Climate Anomaly (950-1250 CE). Almost no fire activity was observed between 1210 and 1300 CE, related to reduced human presence during the dry period. A wetter interval began in 1400 CE, with expansion of the palm swamp and the moisture-related tree/herbaceous taxa Myrtaceae and *Spathiphyllum*, which was synchronous with the Little Ice Age (1400-1700 CE). During this humid phase, agriculture practices were observed by the presence of *Zea mays*. The limited biomass burning with no deforestation at the beginning of the wet interval shifted to extensive fires and deforestation after 1650 CE, giving an age for the arrival of European colonists in the north of Piauí State. Fires stopped after the creation of Sete Cidades National Park in 1961 CE, resulting in the expansion of the Cerrado aboreal cover. This study provides novel knowledge about past human occupation of Northeastern Cerrado, defined by three types of land use practices (indigenous, colonists and protection policy) and shows how important it is to include historical aspects of the landscape for future conservation scenarios.

Vegetation and fire responses to late Quaternary climate and human forcing in Santa Catalina Island (California, USA)

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Situated west of Los Angeles, and having experienced a lesser urban development than the adjacent continental coast, the California Channel Islands (CHIS) are acknowledged as one of the few remaining natural Mediterranean ecosystems in southern California. However, our knowledge of the long-term ecology of this island biodiversity hotspot is still sparse. Most of the available paleoenvironmental information performed on the CHIS focuses in the Holocene, while the information for earlier periods, such as the Late Pleistocene, is still fragmentary.

We present multi-proxy palaeoenvironmental analyses including pollen, non-pollen palynomorph, charcoal and sedimentology in a 520-cm depth record obtained at Echo Lake on Santa Catalina Island, one of the few existing natural wetland basins in the CHIS. The study has allowed us to reconstruct vegetation and fire dynamics during three main periods of lake occurrence within different climatic conditions and anthropogenic pressures: 1) Marine Isotope Stage (MIS) 3 at ~38 ky cal BP, when coastal conifers dominated the landscape; 2) the Late Pleistocene-Holocene (MIS2-1) transition between 13.2 and 8.8 cal BP, a period when conifer woodlands were replaced by more open scrub and grassland, with changing fire dynamics and the arrival of human communities; and 3) the historical period when native flora and landscapes were impacted by agricultural practices introduced by American settlers.

By analyzing vegetation and fire dynamics prior to and after prehistoric and colonial settling we will have a better understanding on how Mediterranean island ecosystems have been impacted by, and responded to, long-term natural climatic and human forces. This is essential for present management and potential restoration of island habitats in a context of climate change and increased population and development pressure in southern California.

Palaeoecological insights in coastal landscape evolution. Late Holocene vegetation changes in Southern California

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The California coast is a Mediterranean biodiversity hotspot attesting to a long and rich anthropogenic history over the last ~13.000 years. Human migration, trading and colonization have had a direct impact on biodiversity and vegetation structure and distribution. Southern California (SoCal) has witnessed intense landscape management and different land-use strategies through time, especially during the Late Holocene, and particularly over the last ~250 years, when urban development and the introduction of agricultural practices in coastal areas ultimately became a major threat to coastal biodiversity and natural resources.

In this study we present palaeoecological results obtained in the Santa-Barbara coastal region as part of the MeSCAL Agence nationale de la recherche (ANR) project, which aims to analyze the vegetation composition and distribution, biodiversity, and landscape transformation following natural dynamics and/or prehistoric and colonial migrations and settling over the last 4000 years in SoCal. High-temporal resolution pollen and non-pollen palynomorphs analysis has been conducted over the Late Holocene section from the marine core MD02-2503, obtained ~ 20 km offshore of the Santa Barbara coast.

Palynological datasets have been integrated with available paleoclimatic series and continental palynological datasets, as well as with archaeo-historical information of human mobility, settling and coastal landscape management. This has allowed us to calibrate regional and local changes in biodiversity, vegetation composition and land-use, and to discriminate those transformations due to environmental, climatic and/or anthropic dynamics. This research helps to place in value the role played by anthropogenic-climate interaction in shaping the current floristic richness, vegetation and landscape diversity in Santa Barbara coastal region. This study provides new tools for future management and ecological conservation of this endangered biodiversity hotspot in SoCal.

Dinocysts and others Non-Pollen Palynomorphs from the Mar Piccolo basin (Taranto, southern Italy) at the Pleistocene-Holocene transition

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The Mar Piccolo (Taranto, southern Italy) is a semi-enclosed basin with a low hydrodynamism, fed by both an ephemeral network of streams and sub-aerial and submarine karstic springs. The Mediterranean water exchange is ensured by two channels that connect the Mar Piccolo to the Gulf of Taranto (northern Ionian Sea). Here we present the results of dinocysts, Non-Pollen Palynomorphs (NPPs) and morphosedimentary analyses carried out in the portion of core S05B (29.15 m thick) including the Pleistocene-Holocene transition. The basal record includes palynological assemblages (e.g., *Zygnemataceae*) typical of pond freshwater paleoenvironments with flowing streams probably fed exclusively by karst springs, interspersed with moments of high accumulation of organic matter (e.g., *Trachelomonas*). The first significant occurrence of marine dinocysts (at 23.91 m from the base) attests the ingression of saline waters from the Gulf of Taranto and the instauration in the Mar Piccolo of prevalent brackish conditions. However, dinocysts show a quite discontinuous stratigraphical distribution marked by disappearance vs occurrence events, in a prevalently very low water column. The portion including the tephra, dated at 8.9 ka (at 18.50 m), towards the top of the record, corresponds to an interval marked by an increase in dinocysts concentration during a saline water input from the Gulf of Taranto. The latter possibly correlates to the Melt Water Pulse - 1c (MWP-1c; at ca 9.4 ka - 8.3 ka). Just after (18.06 m) cold dinocysts increase possibly as a response to the 8.2 ka event. A subsequent new strong decrease (from 18.06 to 16 m) in the saline water supply together with an increase of the springs freshwater contribution mark the top of the record characterized by a new organic rich phase.

Paleoenviromental reconstruction of Mar Piccolo (Taranto, Southern Italy) at the transition Pleistocene-Holocene

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Morphoclimatic changes have been traced by palynological (pollen and palynofacies) and morphosedimentary analyses of the sediment of the S05B core retrieved from the Mar Piccolo basin (southern Italy) throughout the Pleistocene-Holocene transition. From 29.10 to 25 m, the analysis of organic matter both structured and amorphous one suggests an early environment characterized by very shallow water and anoxic ponds. Steppic (e.g., *Artemisia*, *Ephedra* s.l.) and halophyte pollen taxa (e.g., *Armeria,* Amaranthaceae) dominate suggesting prevalent arid climatic conditions on the land. Salt marshes were submitted to several freshwater inputs, as attested by the increasing in Cyperaceae, and freshwater algae. The expansion of freshwater marshes apparently developed under anoxic/disoxic conditions of the bottom and still arid atmospheric conditions. However, at the beginning of the Holocene, a sudden increase of several arboreal taxon (e.g., *Quercus pubescens*, *Pinus*) mark the instauration of progressively warmer and humid conditions. The arrival of marine waters in the basin promotes increasingly oxygenated conditions of its bottom as attested by the organic matter content. Between 26 m and about 16 m, at least six abrupt increases of the open vegetation (steppes, salt marshes and freshwater marshes) have been detected. They represent sub-millennial climatic changes, possibly related to Bond events with the younger one, just above the Pomici di Mercato tephra (at 18.5 m, dated at 8.9 ka), approximating the 8.2 ka (Bond event 5). The detection of such rapid arid events contributes to the chronological framework reconstruction of the sedimentary basin infill. Insights on the resilience of the Mar Piccolo ecosystems, maintenance of biodiversity under the effects of latest Quaternary climate change including current global warming will be developed.

Palynological analysis of mosses and sub-recent surface sediments from the Orbetello and Burano coastal lagoons (central Italy)

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The Orbetello and Burano lagoons (southern Tuscany, Italy) together with the neighbouring areas, are preserved by Natural State Reserves. They are also Sites of Community Importance and Special Protection Zones and Wetland of International Values (Ramsar Conventions on Wetlands). These are unique examples of ecosystems in terms of naturalistic richness and biodiversity despite their preservation is now threatened by the effects of global warming, water pollution, growing anthropic impact, the latter especially evident in the Orbetello Lagoon.

Samples of mosses around the lagoons and at sediment–water interface have been collected from several locations. All samples have been processed at the Palynological Laboratory of the University of Florence. The study of modern and sub-recent palynological assemblages and their relationship with present-day vegetation permitted paleoecological reconstructions as well as the identification of pollen indicators from different environments or plant communities. Sub-recent pollen spectra exhibit assemblages dominated by Mediterranean and sub-Mediterranean arboreal/shrubs taxa (especially *Quercus ilex* but also deciduous *Quercus* and *Pinus)*. The herbaceous vegetation taxa (e.g. Amaranthaceae, Cyperaceae and Poaceae) show different occurrence and abundance in the different pick-up points pointing out local expansions or retractions of specific environments and their associated vegetation. The anthropic impact is attested by the massive occurrence of *Olea* as a result of the introduction of this crop since ancient times but also by more recently introduced exotic plants (e.g. *Eucalyptus*). *Ruppia* and algae acme phases pointed out several environmental episodes, which have been related to anthropic or climate impacts as well as to their interplay (such as eutrophication, lowering of water level, etc.). Other already available palynological records documenting the last 7 ka in the same and closer sites are also evaluated.

The incoming integration with parallel studies, in the same two sites, devoted to ostracods and molluscs will allow a detailed reconstruction of recent environmental changes and response to anthropic impact and global warming, in both aquatic and on land environments, in these important hotspot areas of the central Mediterranean.

An assessment of the human-driven physical harm on the seabed of Augusta Bay (Southern Italy, Western Ionian Sea), achieved by geophysical investigations and direct samplings

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In this study we explored the extent of the human-driven physical impact on the continental shelf of the Augusta Bay (Southern Italy, Western Ionian Sea), by means of swath bathymetry, side-scan sonar images and Chirp sonar profiles, as well as direct seabed samplings. The Augusta Bay includes the Rada di Augusta, a wide littoral sector sheltered by breakwaters and engaged in harbour activities, and the Priolo inlet, both listed in the National Remediation Plan (NRP) by the Italian Ministry of Environment. Indeed, extensive petrochemical and industrial activities, military and commercial maritime traffic, as well as agriculture and fishery activities, have resulted in a highly complex combination of impacts on the marine environment and seafloor.

Our investigations highlighted that at least seven categories of anthropogenic footprints, i.e., anchor grooves and scars, excavations, trawl marks, generic targets, dumping trails, isolated dumping and dumping cumuli, are present at the seafloor, with higher concentrations observable in the central sector of the bay, between 50 and 100 m bsl. The practice of dredge spoil dumping, possibly long protracted during the last century, has altered the seafloor morphology of the central continental shelf, by forming a mounded deposit, with acoustic features noticeably different from those of any other shelf lithosome originated by natural processes. An original thematic map of the seafloor, describing the seemingly natural sediment facies and the marks of the anthropogenic disturbance, was drawn up useful as a reference benchmark, relative to the early 2000s, for future monitoring or, in general, for spatial planning actions. Finally, a semi-quantitative evaluation of the human-driven harm to the seabed was provided by ranking discretized portions of the shelf area, in function of the occurrence of multiple anthropogenic stressors. This procedure could offer crucial advances to learn more on the effects of human impact on the delicate seafloor environment and its ecosystem and, consequently, provide a solid basis for environmental protection and restoration.

Reconstruction of the dry forest in north-western Madagascar during the late Holocene and its relevance to biodiversity conservation

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Madagascar's western dry deciduous forests have been identified as priority conservation ecosystem due to the high rate of endemism and intense anthropogenic pressure. Deforestation, interpreted without empirical understanding of landscape history and fire regimes, results in generalized assumptions of landscape degradation and condemnation of local community land-use. These assumptions have led to policies of general tree planting and fire suppression throughout the island. However, the extent of change, its relative importance and interactions between climate and humans over time are poorly understood particularly in the northwest part of the island. This raises question for what conservation management should be planned as reference conditions are lacking. In this research information and changes over time in open vegetation in the northwest Madagascar are explored. The vegetation dynamic and its relationship with human activities (herbivory and fire) are studied using fossil pollen, dung fungal spores and microscopic charcoal from two sediment cores. The first core is a relatively young (c□100 BP), presenting opportunities for understanding recent changes of landscape. The second covers a much longer timespan (c□2000 BP) and gives insight into how vegetation has changed since human settlement. Preliminary results show that the vegetation was a mosaic of dry forest and grassland. It was dynamic at both sites during the last century and two millennia. The dominance of Poaceae and tree families such as Fabaceae, Arecaceae (Palm) and Apocynaceae between ~2500 Cal BP and ~1750 Cal BP is characteristic of an open vegetation in the western region. Despite the increasing of anthropogenic signals in the coprophilous fungi spores and charcoal records, the vegetation was resilient. Shrub and tree were present along the core even though their percentage were slightly decreasing from ~1000 BP. During the last 100 years, the vegetation was a grassland mosaic with abondance of herb, shrub, and scattered tree. This study provides an exploration of vegetation changes in response to fire and herbivory activity through different time scales. This can provide information for a conservation management plan to the dry ecosystem in the western region of Madagascar, with a particular focus on ecosystem restoration and fire policy.

Anthropogenic vulnerability of biodiversity hotspots of Greater Virunga Landscape of the Albertine Rift, East Africa

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This study aims to provide information for the management of wild species in the Albertine Rift of East Africa. The Greater Virunga Landscape of the Albertine Rift has faced historical and continuing threats due to armed conflict, population pressure for land, poaching and fluctuations in political support for conservation. The Landscape supports extraordinary biodiversity and a large human population. Anthropogenic Climate Change is expected to have severe impacts on biodiversity and people. We assessed the climate change vulnerability of mammals, birds, fish, and plants, and gathered detailed information on their use by humans. Overall, this study presents the results of threats to the region's biota. The need for enhancing the productivity of fisheries triggered the introduction of non-native fish, causing dramatic changes to local species. The extensive translocation of Nile tilapia (*Oreochromis niloticus*) is one of the major factors in this respect. Using 10 microsatellite loci and Mitochondrial DNA Sequencing, we amplified a total of 128 individuals to investigate the genetic structure of *O. niloticus* from the Albertine Rift Lakes in comparison to the Lake Victoria Basin populations. The Nile tilapia genetic structure was congruent with both geographical location and anthropogenic activities. For example, most of the populations have gone through a reduction in genetic diversity, which can be a consequence of bottleneck caused by overfishing, genetic erosion due to fragmentation or founder effect. The anthropogenic activities promoted artificial admixture among the East African Nile tilapia populations. These events contribute to outbreeding depression which in turn compromises the sustainability of the species in the region. Freshwater fish, plants and mammals have emerged as the most heavily utilized taxa. Agricultural activities and increased population density were the most significant drivers of the established land use land cover changes. This study has shown accelerated loss of key land cover biomes; grasslands, bush lands, and tropical high forests mediated by anthropogenic factors and leading to reduced landscape heterogeneity thus potential to significantly affecting ecosystem services supply in this region. The hotspots of Land use/land cover change was predominant on privately owned land, refugee settlement area, and areas with oil and gas industry developments.

Human induced switch in coastal ecosystem dynamics: Proxy records from Western Indian Estuary

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Estuarine sedimentary records from India have rarely been exploited to reconstruct past environmental or climatic history. In a deliberate attempt to assess the potentials of such estuarine sedimentary archives a 1 m sediment core was collected in the lower tidal flats of an important estuary, along the Central West Coast of India. Coupled measurements of Pb-210 and Cs-137 helped generate reliable geochronology with a resolution of 2 to 3 years per sample on the core and asserted its suitability for reconstruct of high- resolution climatic records. Downcore variability of Foraminiferal and clay mineral assemblages as well as sediment textures were generated as proxy records for reconstructing century long environmental and hydrological conditions in the estuary. This study also compares the proxy records vis. with instrumental records for climate which show very good correlation throughout the length of the core. It is interesting to note that every drought period instrumentally recorded in the past century is manifested in the study area by the clay mineral assemblage. The present study demonstrates the sensitivity of clay minerals at smaller time scales and validates their applicability in high resolution monsoon reconstructions. The foraminiferal assemblage shows a switch in ecosystem dynamics complementary to increased development and urbanisation in the watershed of the estuary under study.

Conservation status of biological resources and archaeological remains of the historical and ecotouristic site of Yaoui (Centre-Benin) in a context of anthropic pressures

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The conservation of historical sites and related natural resources is of paramount importance for the preservation of past achievements. This research focused on the biological resources and archaeological remains of the Yaoui ecotourism and historical site (Central Benin). The site is located in a crystalline peneplain zone and is characterized by a series of three hills with altitudes varying between 276 and 461 m. The goal of this research conducted by a multidisciplinary team is to inventory the biological resources and archaeological remains of the site. The methodological approach used is floristic inventory techniques, archaeological excavation methods and diachronic analysis from sentinel images of 2016 and 2021. A total of 142 plant species divided into 49 families were identified within a diversity of plant communities with the presence of species with national and international conservation status. The site has archaeological potential including a sub-rock shelter inside which is erected the altar of a deity. Variously decorated pottery shards and anthropic mounds were inventoried, some of which are about 1 m high. With regard to the archaeological material, several places with high concentrations of ceramics were found on the surface of certain mounds. It should be remembered that anthropic mounds are accumulations of sediment in the form of mounds due to human activities where material witnesses of these activities can be identified such as pottery shards, pipes, millstones, wheels, bones, ash, etc. Between 2016 and 2021, the spatial mutations observed were more in favor of anthropogenic formations including plantations and crops and fallow land. The main factors of pressure on natural resources identified on the site are agricultural practices, logging and palm wine indices, carbonization sites. In the face of such practices, it is essential to take measures to preserve the integrity of the site.

Multi-tracers unravel the threats to coastal ecosystems dependent on groundwater during droughts

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Groundwater resources can supplement diminishing surface water supplies in regions such as semi-arid South Africa which receives less than half the global mean annual precipitation. These resources are generally underdeveloped and many of the country's large cities rely on surface water instead for potable supply. An exception is seaside villages, where groundwater is an important residential water source. For the most part, however, groundwater is considered a reliable emergency resource during drought conditions. Due to population growth, socioeconomic development and effects of climate change, several South African water supply systems are severely constrained. Local governments are injecting water from coastal springs to main water supply pipelines where it is blended with surface water. Groundwater-dependent ecosystems, such as the actively precipitating supratidal microbialite ecosystems, occur along the southern South African coast and have recently been studied. The intricacies of these ecosystems are being illuminated through ongoing investigation, and they may be negatively impacted by large-scale groundwater abstraction. These ecosystems are especially important in terms of palaeoscience, heritage and biodiversity as they are considered partial analogues for Archaean stromatolites and host endemic biological species. Yet, little is known regarding the groundwater origin and dynamics on which the microbialite pools rely for accretion. This local multi-tracer study presented here (including stable environmental isotopes, trace organics, and age tracers) is the first attempt to investigate the nature of the groundwater entering Eastern Cape microbialite pools in terms of its source, anthropogenic inputs, and residence time. This is especially relevant regarding the multi-year drought in the region and the conservation management of these microbialite systems in the face of increased groundwater use.

Session 145: Climate Records from Coastal Systems

Coseismic subsidence, accommodation space, and the preservation of storm and tsunami deposits in coastal ponds on Anegada, British Virgin Islands

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Land-falling hurricanes pose an economic and environmental hazard to Atlantic Ocean and Caribbean Sea coastlines. Patterns of their frequency and intensity under a warming climate remain unclear in part because detailed long-term records are limited to only a few locations, but also because of uncertainties associated with interpreting the geologic record (e.g., preservation/erosion of older deposits, distinguishing between storm and tsunami deposition, availability of accommodation space). We improve upon this uncertainty by utilising datasets obtained from more than a decade of coastal investigations on Anegada, British Virgin Islands, including: (1) historical, geological, and modelling studies of tsunami deposits originating from both far-field (e.g., 1755 Lisbon tsunami) and near-field (e.g., originating from the Puerto Rico trench) tsunamis; (2) modern sedimentological analogues and post-event field surveys of landfalling hurricanes; and (3) onshore and offshore surface sediment samples for use in provenance analysis. This study uses the existing datasets as a basis for comparison on a series of overwash deposits preserved within coastal salt ponds on Anegada. Accommodation space within the salt ponds has been influenced by geomorphologic changes along the coast due to inundation by unusually large tsunamis and possible coseismic subsidence associated with Puerto Rico trench earthquakes. As a result, the overwash record on Anegada can be patchy and susceptible to erosion by subsequent marine inundation events. To ensure the longest and most complete record of overwash deposits, we accessed areas within salt ponds where accommodation space is maximised and potential reworking by subsequent events minimised. We used *Homotrema* taphonomy and elemental geochemistry to reveal differences between storm and tsunami deposits, where tsunami deposits contain Br and high abundances of *Homotrema* fragments that are generally vibrantly coloured, suggesting scouring and transport by tsunami, followed by rapid burial on the coast. In contrast, hurricane deposits are characterised by both Br and Ti and near equal abundances of bleached and non-bleached *Homotrema,* suggesting that at least 50% of the sediment was sourced from reef flat areas close to shore. Constraining the origin of overwash deposits at this location is essential to the establishment of effective coastal hazard mitigation policies.

Late Holocene paleostorm reconstruction based on XRF core scanning and sedimentological data from two coastal ombrotrophic peat cores, the Magdalen Islands, Québec, Canada

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Storms are pervasive dangers to coastal communities in Eastern Canada and, under future climate scenarios, these extreme weather events are projected to increase in frequency and intensity. However, the impacts of climate change on storm variability have not been studied extensively in this region, in part due to the short and incomplete instrumental storm record. Here we present a new, high-resolution record of storms over the late Holocene, based on the analysis of cores of 3.25 m and 7.00 m length from two ombrotrophic peatbogs on the Magdalen Islands, in the Gulf of St. Lawrence. The cores were dated by ^{14}C and ^{210}Pb, with the bottommost peat sediments dating to ~4920 BP and ~4720 BP, respectively. We applied principal component analyses (PCA) using 10 elements measured by XRF core scanning to understand sediment provenance. Our results indicate the presence of aeolian sediments from local beach sand and sandstone cliffs characterized by the presence of K, Ti, Si, and Zr. We used a combination of aeolian sand and titanium content to identify allochthonous sediments that were deposited during extreme weather events, and validated these using the instrumental hurricane record from the Magdalen Islands from the past 150 years. Our storm reconstruction indicates a particularly active period between 1400-1650 CE, when heightened activity was also identified in other studies from the northwestern North Atlantic, as well as a notable increase in storms since 1930 CE. While warm sea-surface temperature (SST) anomalies seem to have contributed to more frequent storms since 1930 CE, the 1400-1650 CE active period occurred during the Little Ice Age (LIA), a period of generally cooler SSTs in the North Atlantic. Our study is the first to use ombrotrophic peat cores to track storm frequency in eastern North America, as well as one of the northernmost on the continent, and highlights the ambiguous impacts of SSTs on mid-latitude storms. Future research should focus on understanding the climatic factors that control storm variation in Eastern Canada, especially over the last millennium.

Reconstruction of hurricane events over the last millennium based on sedimentary records from a coastal lagoon at Cayo Coco, Cuba

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Sediments from coastal lagoons provide continuous records of past hurricane activity. In this investigation, multiple proxies from two cores taken in Laguna Larga (Cayo Coco, Cuba) were analyzed. Based on ^{210}Pb and ^{14}C dating, grain size, and geochemical analyses by XRF core scanning, nine hurricane-induced sedimentological deposits (including both present and past events) covering the last ~900 years BP, were identified and compared with historical hurricane records for the period 1851-2021. A sand layer believed to have been deposited by Hurricane Irma (category 5 on the Saffir-Simpson wind scale), which struck Cayo Coco in September 2017, is associated with an abrupt increase in water level in the lagoon (as detected by data loggers) as well as profile changes at the adjacent beach. The sedimentary units coinciding with the hurricane events were characterized by a higher fraction of sand and minerals, lower organic matter content, and abrupt increases in elements of Ca, Sr, Zr and Br. During the period of study, hurricane activity was found to be related to variation in the El Niño/Southern Oscillation, which permitted a reconstruction of the long-term history of hurricanes in the region and the pattern of these systems in the province of Ciego de Ávila to be interpreted. Given the location of the study area, these results are important from a paleoclimatological perspective, but also in the context of archaeological studies and tourism.

Changes in Estonian climate (1951-2020) and associated coastal behaviour

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Recent intensification of coastal processes is attributed to regional warming, which in Northern Europe, is manifested during colder seasons. In Estonia, warmer winters, longer sea-ice-free periods, and unfrozen beach sediments contribute to erosion during intense storms. Accumulation in deposcenter has also substantially increased, therefore, climatic fluctuations likely impacted the large-scale coastal behaviour. This study investigates the relationships between several climatic parameters and the character and intensity of coastal processes. Changes in air temperature, storminess, and sea-ice cover during 1951–2020 have been analysed at nine sites. To assess the relationships between climate forcings and shoreline response, patterns and rates of erosional-accretionary trends were analysed using GPS geo-location, topographic maps, and photographic materials. The mean annual temperature increased by 2.2–2.6°C during most of the months and the total number of sea-ice days decreased (at some sites, by a factor of two). According to recent studies, the northward shift of cyclone trajectories in Estonia enhanced the westerlies and reduced the northerlies. However, our findings indicate the opposite trend - an increase of storm impact from the N-NE and a reduction from the westerly directions. An increase in N/NE storms has been particularly evident during the past decade, though we have not detected statistically significant changes in storminess. Until the late 1980s, coastal processes were relatively slow and stable. Regime shift in climatic conditions in the late 1980s - early 1990s triggered a rapid intensification of coastal processes. Velocity of coastal processes increased up to 5-fold. Erosional trends extended into transport areas, while the total down-drift accumulation also increased. A new character of coastal processes emerged in 2011: several north-facing beaches began to erode, with high ridges forming to the S-SW. Less than a decade later, erosional indicators such as coarse lag and heavy-mineral concentrations are being covered by new ridges that now buffer these sites from wave impact. On Cape Kiipsaare (Saaremaa Island), sites dominated by erosion since the 1980s, now have a large sandy ridge formed during the past decade. Many similar patterns are likely preserved in ancient ridges (strandplains). Future research will focus on analysing these patterns in greater detail.

Weathering Extremes: storm surges, coastal landforms, two castles and medieval climate change, Scotland.

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Strandplains and barrier beaches are associated with storm surges. However, they are often underutilised as a way to define storm surge events because of their complex morphology and the interaction between relative sea level change and sediment supply. The study site, Caerlaverock, on the west coast of Scotland is at the confluence of the River Nith and the Solway Firth. The Solway is a sediment rich estuary which is prone to storm surges as low pressure systems move quickly northwards up the coast from the southwest.

Caerlaverock's two Medieval castles sit on mid Holocene marine shoreline terraces, relative sea level is considered to have been stable until the last few decades. Seaward lies an extensive prograding strandplain, we propose that this strandplain was formed by increased sediment supply driven by extreme storm events that encouraged both progradation and erosion.

Here we present palaeoenvironmental research that further define the nature and timing of these storm surges. Sediment records from coastal landforms, barrier beaches and related lagoons, as well as sediment traps associated with the archaeology indicate that a series of very large storm surges impacted the coastline, temporarily raising sea level by >2.5m. Here a combination of AMS ^{14}C and OSL dating have been used to better constrain the chronology, resolving the timing of these events and linking these storm surges to changes in northern hemisphere atmospheric circulation and the North Atlantic Oscillation. It is thought that the coastline had experienced significant storminess between 250 BC to AD 1600, with events occurring several human generations before the castles were planned or constructed as well as when they were occupied.

The interdisciplinary nature of this research, the use of novel sediment records and the establishment a secure chronology demonstrates that these smaller scale coastal landforms can provide detailed records of environmental change. Making it possible to link them to larger scale hemispheric climate drivers and determine the impact that these events had on people living on these dynamic coastlines.

Relative sea-level change during the Common Era in Norway: new data from intertidal basins and salt marshes

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New sea-level index points (SLIPs) from low-elevation isolation basins, salt marshes, and intertidal basins bridge the gap between postglacial and instrumental relative sea-level (RSL) data in Norway. Most RSL curves in Norway, constrained by SLIPs from isolation basins, imply steady RSL fall to modern sea level during the late Holocene. While there is a general lack of SLIPs younger than ca. 2000 years, the few curves with one or two SLIPs younger than 2000 years BP hint at accelerated rates of sea-level fall during this period. Conversely, tide gauge records from localities in southwestern and northeastern Norway indicate that RSL may have been rising since ca. 100 years ago. Initial geochemical analyses of sediment cores from southwestern Norway suggest that marine influence has been increasing during recent centuries, possibly due to rates of eustatic sea level rise overtaking residual glacio-isostatic adjustment (ca. 1-2 mm yr^{-1}). In this presentation, the XRF data will be presented and interpreted alongside CT core scans and new results from stable isotope and microfossil analyses on multiple cores from salt marshes and protected, intertidal basins with bedrock sills in southwestern and northeaster Norway. New SLIPs from these sensitive and diverse coastal regions of Norway help to constrain RSL change during the last 2000 years, and provide a basis for improving quantitative projections of future RSL change.

A Holocene shell midden record of marine radiocarbon reservoir and nitrogen isotope changes from northernmost Chile: implications for upwelling and past human occupation

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Shell middens are prehistoric human refuse mounds found throughout coastal northernmost Chile (18-20ºS) where they span more than 9000 years. By radiocarbon dating samples of marine and terrestrial origin along a given stratigraphic horizon from multiple shell middens, estimates of marine reservoir departures from the global marine 14C calibration curve (ΔR) can be obtained. These departures are mostly due to shifts in upwelling intensity as different water masses have different apparent ^{14}C ages. Our well‐replicated ΔR chronology is based on 192 ^{14}C AMS dates from multiple coeval shell middens along 100 km of coastline and spans more than 9,000 years. ΔR values were remarkably stable from 9.2 – 6.7 ka implying very stable upwelling and highly productive marine ecosystems. These values are highly variable between 6.5 – 4.6 ka, with a prominent and well-replicated negative excursion between 5.4 – 5.1 ka. Values increased until 4.3 ka and then remained stable until 3.5 ka. Large fluctuations resumed between 2.9 – 2.0 ka with values during the last 1.5 ka remaining stable and in good agreement with pre-bomb ΔR estimates. We further measured δ^{15}N from 810 samples of sessile bivalves (mytilids) from one of our shell-midden sites (Caleta Vitor) to assess the impact of past shifts of upwelling on nitrogen cycling. Early Holocene sites have high δ^{15}N values (18-34 ‰) whereas Middle Holocene shell middens show much lower values (averaging 17.25 ‰). Starting at 3.5 ka, bivalves show a large 5-6 ‰ drop in δ^{15}N values after which they averaged c. 21 ‰ until 2.1 ka. A shell midden dated to c. 0.5 ka shows lower δ^{15}N values averaging c. 14 ‰ coeval with ΔR values close to 0 ^{14}C yrs BP. Taken together, our record implies that stable upwelling during the Early and Late Holocene was interrupted by strong millennial-scale environmental fluctuations during the Middle to Late Holocene. Such variability is linked to changes in the long‐term behavior of El Niño‐Southern Oscillation (ENSO) and the South Pacific High (SPH) and had profound consequences for past coastal populations which saw major collapses in northern Chile during the Middle to Late Holocene.

Reconstructing Holocene fire records using dune foot-slope deposits at the Cooloola Sand Mass, Australia

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In this study, we assess charcoal records from aeolian deposits within the Cooloola Sand Mass, a sub-tropical coastal-dune system in eastern Australia, to determine whether they can be used as a proxy for Holocene fire history. We excavate four profiles in depositional wedges at the base of dune slipfaces (foot-slope deposits) and calculate charcoal concentrations for three size classes (180-250 µm, 250-355 µm, and 355 µm-2 mm) at predetermined depth intervals. Age-depth models are constructed for each profile using radiocarbon measurements (n=46) and basal OSL dates (n=4). All records appear intact with little evidence of post-depositional mixing as demonstrated by minimal age-reversals and consistent trends in charcoal concentration and accumulation rates (CHAR) amongst size classes. Aggregating all four records, we generate a ca 7 cal ka BP terrestrial fire history that depicts distinct peaks representing periods of increased local fire activity: ca. < 0.1, 1.1-0.3, 2.2-1.8, 3.6-2.6, and 6.7-5.3 cal. ka BP. Our findings parallel regional records and highlight their utility as an ecological and geomorphological record that is both spatially continuous and abundant across the landscape. As dune fields are much more common than wetlands and lakes in semi-arid and arid areas, these deposits have the potential to increase the spatial resolution of fire records globally.

Session 147: Sea-Level, Ice-Sheet, and Earth system evolution: understanding the past to constrain the future

One or two peaks? Rates of Holocene sea level rise using sea-level data from the southern north sea.

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In contrast to the numerous land-based collections of Holocene relative sea level (RSL) data, there are relatively few early Holocene records that are continuous and from the offshore area. This will impact on how well the rates of early Holocene sea-level rise are constrained, which is key to understanding early Holocene deglaciation patterns and future rates of sea-level change. We addressed this gap by conducting a dedicated offshore data-collection campaign across the southern North Sea. This area has evolved from a large continental shelf to the current submerged landscape as global sea level rose driven by the deglaciation of the major continental ice sheets and the subsidence of the Eurasian ice sheet (EuIS) forebulge

Our new and updated dataset of 88 sea level index points and 78 limiting points, extends from 13 ka to 3 ka BP and is corrected for both paleo-tidal changes and ongoing background tectonic subsidence. The combined dataset show that RSL rose steadily at a rate of ~ 8 mm/yr, with two pronounced peaks of ~15 mm/yr at 9.3 ka and 8.2 ka BP.

To understand what was controlling these rapid peaks in sea level rise, we used both a 1D and 3D GIA model combined with two alternative reconstructions for the EuIS complex. We found that across the study region the spatial variation in RSL was controlled by the EuIS, contributing over 50% of the total signal in the central North Sea, increasing to over 80% close to the current coastline. Removing the predicted EuIS signal from our new dataset we will provide new estimates of the rates of Holocene sea level rise and the possible existing of two periods of rapid sea level rise during the Holocene.

Noisy Input Generalised Additive Models for RSL Change along the East Coast of North America

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1. Maynooth University, 2. Tufts University

The 2021 Intergovernmental Panel on Climate Change report highlighted how rates of sea level rise are the fastest in at least the last 3000 years. As a result, it is important to understand historical sea level trends at a regional and local level in order to comprehend the drivers of sea level change and the potential impacts. The influence of different sea level drivers, e.g thermal expansion, ocean dynamics and glacial isostatic adjustment (GIA), has changed throughout time and space. Therefore, a useful statistical model requires both flexibility in time and space and have the capability to examine these separate drivers, whilst taking account of uncertainty. Our project aims to develop statistical models to examine historic sea level changes for North America's and Ireland's Atlantic Coast. For our models, we utilise sea-level proxy data and tide gauge data which provide relative sea level estimates with uncertainty. The statistical approach employed is that of extensions of Generalised Additive Models (GAMs), which allow separate components of sea level to be modelled individually and efficiently and for smooth rates of change to be calculated.

The model is built in a Bayesian framework which allows for external prior information to constrain the evolution of sea level change over space and time. The proxy data is collected from salt-marsh sediment cores and dated using biological and geochemical sea level indicators. Additional tide gauge data is taken from the Permanent Service for Mean Sea Level online. Uncertainty in dating is extremely important when using proxy records and is accounted for using the Noisy Input uncertainty method.

By combining statistical models, proxy and tidal gauge data, our results have shown that current sea level along North America's east coast is the highest it has been in at least the last 15 centuries. The GAMs have the capability of examining the different drivers of RSL change e.g. GIA, local factors and barystatic influences. Our models have demonstrated that GIA was the main driver of RSL change along North America's Atlantic coast, until the 20th century when a sharp rise in rates of sea level change can be seen.

Multi-evidences of MIS 3 marine deposits from Baeksu tidal flats, southwest coast of Korea suggest much higher relative sea-level than previously we thought

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Reconstructing of sea-level position during Marine Isotope Stage 3 (MIS 3, 29-57kyrs BP) is challenging due to the highly dynamic climate conditions, as recorded in Greenland and Antarctic ice cores. Global mean sea level (GMSL) has been documented to vary in the range of -55 to -80 m at 44 ka. However, the location of the GMSL at that time is still controversial due to a lack of data, especially in continental marginal seas. More recently, some works suggest that GMSL during MIS 3 reached -35 to -40 m based on analysis of sediment core records with the revised ICE-5G ice history and GIA model, implying that the sea level during MIS 3 may be much higher than previously documented. In this regard, we analyzed two borehole cores from the Baeksu tidal flats, the southwest coast of Korea (the eastern Yellow Sea) to constrain the sea level changes during MIS 3. Sedimentary facies of the cores were analyzed with geochemical and micropaleontological compositions, providing information for better understanding the depositional environments of each facies. Age models of the cores was reconstructed by OSL dating. Our results reveal that the tidal deposits are stratigraphically composed of 1) basal fluvial gravels, 2) mudflat/saltmarsh (MIS 5e), 3) saltmarsh/mudflat (MIS 5a/b), 4) gravelly spit/mudflat (MIS 3), 5) tidal flat/intertidal shoreface/sandy beach deposits (Holocene) in ascending order. They are grouped into two sequences by subaerially exposed, oxidized layer, with an unconformity-bounded subsequence. Conclusively, three transgressive depositions are recorded, but one regression deposition is only represented by basal gravel lag and oxidized layer. Notably, ichnofacies and the heterotrophic dinoflagellate assemblages highlight that the mud deposition, corresponding to MIS 3, was accumulated in tidal environments. Considering constant tidal range and previous GIA model results during the last Pleistocene in the eastern Yellow Sea, the sea level during MIS 3 was likely in the range of -14 to -18 m. However, the actual cause of such higher sea-level remains still under discussion. In addition, records of MIS 3 deposition in the sediment cores from additional locations will be necessary for defining the high frequency of sea level curve.

Distinction of relative sea level driving forces in the Southern Adriatic during the Late Holocene

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The relative sea-level (RSL) change is a sum of effects of processes acting on different scales. The high-resolution study of RSL change based on *Lithophyllum* rims allows us to distinguish local from regional and global contributions. The studied islands in the Southern Adriatic are part of Elafiti island group. They are located near the external front of the Dinarides where seismicity in Croatia attains one of the highest levels. Studying the RSL markers: *Lithophyllum* rims, *Lithophaga lithophaga* borehole upper limits and tidal notches we identified two uplifted palaeoshorelines, 60-90 cm and 25-40 cm above MSL. The high-resolution geochronology built on algal rims enabled the distinction of coseismic uplift events from subsidence periods. As a result, we provide new, field-based reconstruction of palaeoearthquakes and describe spatial patterns of differential uplift, providing new data on active tectonics at the Elafiti islands.

Two major seismically triggered uplift events have been differentiated at the Elafiti related to the Pelješac-Dubrovnik fault zone pointing to repeated earthquakes of magnitudes exceeding Mw = 6.5. The earlier, older events, caused larger displacements (60-80 cm) related to 4th to 6th century AD and 750-1100 AD earthquakes, while the later, younger events, revealed on average lower displacements (40-55 cm) corresponding to the 1520 AD quake and the 1667 Dubrovnik earthquake.

The distinction of local coseismic displacements of RSL change together with the obtained regional glacio- and hydro-isostatic adjustment estimates of 0.34 mm/yr allow us to approach the global contribution. The global sea-level component revealed low amplitude variations <±0.20 m corresponding to previous observations.

The RSL change generally vary between of 0.3 to 0.4 mm/yr while after 1800 cal AD the rates of RSL change increased up to 1.4 mm/yr, confirming the acceleration of RSL rise. This high-resolution study allows us to better approach the driving mechanisms of RSL change, thus providing new insight into the late Holocene sea-level history of the southern Adriatic, which is of utmost importance for the improvement of future predictions and for seismic hazard assessment. This research was supported by Croatian Science Foundation HRZZ-IP-2019-04-9445–Relative sea-level change and climate change along the eastern Adriatic coast–SEALeveL.

The use of the Last the Glacial Maximum to improve projections of future Greenland

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Climate and ice sheets are projected to change substantially in future centuries, evolving beyond anything observed in the recent past. Yet, models used for projecting future ice sheet behaviour (and associated sea level rise) are often only calibrated for modern climate conditions. This raises the fundamental question: do our models have sufficient flexibility and core predictive skill to simulate the out-of-sample conditions of the future?

When applying a version of the recently developed FAMOUS-ice coupled climate-ice sheet model to the Last Glacial Maximum, the simulated North American ice sheet collapsed. The model had been calibrated to reproduce modern ice well, but our subsequent palaeo application revealed unexpected behaviours when simulating very different climate conditions from today.

Here, we present a large ensemble of several hundred coupled climate-ice sheet simulations of modern and future Greenland, and the Last Glacial Maximum North American ice sheets. With this ensemble, we explore the influence of uncertainty in the model inputs (parameter values). We evaluate model performance against a new suite of metrics for characterising ice sheet and climate conditions at the Last Glacial Maximum and present, and we identify versions of the model that optimise model performance in both time periods. With this improved model, we project future ice sheet evolution (RCP8.5), and examine the relationship between past, present and future ice sheets with each model configuration in order to understand how constraints on past ice sheets influence future projections.

Information from the past may not narrow down the uncertainty in our future projections, but the increased flexibility and predictive skill of models that have been assessed against palaeo data produce more robust projections with higher confidence in the results.

New constraints on Late Pleistocene relative sea-level changes in northwest Scotland- Beach to Basins: GIA Feedbacks

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Reconstruction of past ice sheet behaviour and relative sea-level changes provide important analogues of how contemporary systems may respond to climate change. Due to the presence of the British and Irish Ice Sheet and the Minch Ice Stream during the Last Glacial Maximum, the northwest of Scotland provides critical records for testing models of the interplay between ice-sheet retreat, glacio-isostatic adjustment, and relative sea-level changes. We provide new constraints on Late Pleistocene (~17-14 ka) relative sea-level limits and changes from raised beaches and isolation basins along the former Minch Ice Stream. These features provide ages of the first ice-free conditions and the oldest relative sea-level records following the last glacial maximum. Such data are key to improving GIA models for this region, whose estimates of relative sea-level change deviate by as much as 100 m during this time period. By improving the understanding of sea-level change along the former ice stream, we can also investigate the importance of sea-level feedbacks to marine-based ice sheets during their retreat, providing insights into potential behaviours of contemporary marine-based ice sheets.

5000 years of relative sea-level change in New Jersey: Quantifying the roles of sediment compaction and glacial isostatic adjustment

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Stratigraphic data from salt marshes provide accurate reconstructions of Holocene relative sea-level (RSL) change and necessary constraints to models of glacial isostatic adjustment (GIA), the dominant driver of late Holocene RSL rise along the U.S. mid-Atlantic coast. However, salt-marsh sediments are prone to compaction, which can result in an overestimation in the rate of reconstructed RSL rise. RSL reconstructions must consider the contribution of local processes such as sediment compaction to accurately decipher the driving processes.

Here, we compare compacted and compaction-free mid- to late-Holocene RSL records from a salt marsh in southern New Jersey. One record uses basal peats that have minimal sediment compaction because they overlie an incompressible substrate. Ages of the 14 basal sea-level index points range from 1211 ± 56 to 4414 ± 112 years BP. Using a spatiotemporal statistical model, the basal peat record shows that RSL rose 8.6 m at an average rate of 1.7 ± 0.1 mm/yr from 5000 years BP to present. The second record utilizes a continuous ~9 m, 5000 year-long, compaction-prone core consisting of peats and muds. We used a geotechnical model to estimate post-depositional lowering (PDL) resulting from sediment compaction and found a maximum PDL estimate of ~0.65 m in the middle of the core at ~5.5 m depth. Initial results from radiocarbon dates of the continuous core show an offset up to ~1 m compared to the basal samples, highlighting the influence of sediment compaction within deep continuous sequences of salt-marsh sediment.

Our compaction-free record also allows us to compare RSL changes with an ensemble of 1D (laterally homogenous) and site-specific 3D (laterally heterogeneous) GIA models. The models tend to overestimate the magnitude of RSL rise over the last 5000 years and do not reproduce the linear trend revealed by the RSL data. These discrepancies may imply the ice-equivalent sea-level signal in the ice models needs to be refined. The continued divergence of RSL data and GIA models highlights the importance of testing a wide array of ice-model and viscosity-model parameters to simulate GIA histories that more precisely fit site-specific RSL data along the U.S. mid-Atlantic coast.

Simulating Antarctic Ice Sheet evolution from the mid-Pliocene to present day and beyond

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The retreat of the Greenland and the Antarctic ice sheet (AIS) and the resulting sea level rise is one of the major long-term challenges posed to humanity by anthropocentric climate change. While Antarctic ice masses would increase sea level up to ca 58 meters when completely melted, the response of the ice sheet to drastic changes in the climate system is still very uncertain. Especially, during the mid-Pleistocene Transition (MPT) the role of Antarctica both as a driver and responder to climate change is unknown. Thus, and in expectation of the results of the Beyond EPICA Oldest Ice project, it is important to gain a better understanding about the role of Antarctica in and on the climate system and sea level change throughout the Pleistocene.

Here, we use the Parallel Ice Sheet Model (PISM) to simulate the transient evolution of the AIS from the mid-Pliocene, through the MPT, to present day and into the future. We force the model with a climate matrix approach which interpolates between individual climate model snapshots from PMIP4 following different climatic forcing time series. The climate matrix approach enables us to account for the main feedbacks relevant for ice sheets as well as giving the opportunity to investigate the response of Antarctica to individual forcings (e.g., orbital, CO2, sea level).

With our study we aim to better understand the evolution of Antarctica during the Pleistocene and how it changed during the MPT. Further, we want to clarify the influence of the individual forcings and related processes onto those changes. Findings from this study will not only help to improve our understanding of past sea level changes but also inform on potential Antarctic trajectories.

Underestimated vertical land motion component in sea-level projections – a case study from the Oka estuary, northern Spain

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Long-term trends of vertical land motion (VLM) are an important component in relative sea-level (RSL) projections, especially at regional to local scales and over the short to medium term. However, VLM is difficult to derive because of a lack of long-term instrumental records (e.g., GNSS, tide gauge) and their sparse distribution globally. Geological data reveal RSL histories over thousands of years and their comparison with glacial isostatic adjustment (GIA) models can isolate the long-term VLM signal. The geological VLM signal can be validated with nearby GNSS data and incorporated into sea-level projections.

Here, we present a case study from the Oka estuary, northern Spain. We apply two GIA models for the Atlantic coast of Europe with different ice model inputs (ICE-6G_C and ANU-ICE) but the same 3D Earth model. Both models fit well with the late Holocene RSL data along the Atlantic coast of Europe, with misfit statistics < 1.5, except the Oka estuary region, where both models show notable misfits with misfit statistics > 3.8. The significant misfits of both models in the Oka estuary region are indicative of local subsidence during the late Holocene. Moreover, the nearby GPS (station SCOA) with records > 17 years shows a VLM rate of -1.16 0.53 mm/yr compared to -0.15 0.40 mm/yr to -2.48 0.37 mm/yr elsewhere along the Atlantic coast of Europe. The VLM rate of SCOA accounts for the misfit between the GIA models and RSL data in the late Holocene. The VLM rate incorporated in IPCC AR6 projections in Oka estuary is ~0.35 mm/yr, which is only ~30% of the derived long-term VLM rate of -1.16 0.53 mm/yr, underestimating the projected sea-level rise rate by 17 - 25% by 2030 and 12 - 18% by 2050 under the five Shared Socioeconomic Pathway (SSP) scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5).

Multiproxy late-Holocene sea-level reconstructions along the South African coastline

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Global mean sea level is predicted to rise by up to 0.8 m by the year 2100 according to the latest IPCC report. The southern African coastline is vulnerable to sea level rise due to a lack of detailed understanding of past sea-level changes and coastal evolution and how to use this knowledge to adapt to future sea-level rise. To understand how South African coastlines will respond to future sea level rise and mitigate appropriately using risk-based strategies, it is important to understand sea level behaviour and coastal evolution from the recent past. In South Africa, sea level records from the Holocene have low spatio-temporal resolution due to the poor preservation of appropriate sea level proxies and lower-precision radiocarbon dating techniques previously available. Existing records are discontinuous with large vertical error, making these records unreliable analogues for sea level change in the near future. We explore new methods of RSL reconstruction using a multiproxy approach to produce high precision RSL reconstructions (+/- ~10 cm or less) over the last two millennia from temperate saltmarshes. We combine new modern diatom assemblage data with existing foraminifera data from two South African salt marsh sites, the Berg and Kromme estuaries, to build the first multiproxy regional Bayesian Transfer function for southern African sea-level reconstruction. We compare model performance and analogue closeness of single, multiproxy, regional and site-specific transfer function methods to achieve the best balance in performance and precision. We apply the best performing transfer function to fossil foraminifera and diatom assemblage data to produce a sea level curve for the region. This reconstruction helps to constrain how much higher RSL has been than present during the late Holocene, thus providing insight into appropriate mitigatory measures that the South African coastal authorities can employ as part of a sea level adaptation strategy.

Reconstruction of relative sea-level change using phreatic overgrowths on speleothems in the Kvarner area (Croatia)

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The research of relative sea-level change along the eastern Adriatic is conducted within the SEALeveL project (HRZZ-IP-2019-04-9445) funded by Croatian Science Foundation. We present results of Holocene relative sea-level changes in the Kvarner area obtained from the first phreatic overgrowths on speleothems (POS) discovered in Croatia. Initially discovered in Mallorca, POS has been found and used as a sea-level marker in only a few world locations. Nonetheless, these researches confirmed that POS is a reliable sea-level index point. POS are carbonate incrustations that form around submerged speleothems and cave walls in coastal caves where sea-level controls the groundwater level. It precipitates at the very top of the water column, i.e. at the water-air interface, their occurrence is restricted to a limited zone of tide-induced groundwater level variation. Since their occurrence directly identifies the height of the sea-level at the time of the carbonate deposition which can be accurately dated using radiometric methods. Our POS samples were collected by SCUBA cave diving in a submerged part of Medvjeđa špilja Cave on Lošinj island (Kvarner region) at several depths between ~1 and 2 m, below mean sea level. XRF and XRD analyses revealed fibrous calcite resembling aragonite. For dating, both the U-Th and radiocarbon methods were used providing insight into Holocene relative sea-level changes. At 3 ka BP the relative sea level was around 1 m below the actual mean sea level. The results from Mali Lošinj island are further integrated into the composite 5000 yrs. relative sea-level curve reconstructed from various markers from the western and eastern coast of Istria.

Coastal indicators of sea level changes in the northwest Africa from the Upper Pleistocene to the Holocene

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Relict evidence of sedimentary and geomorphic features, such as marine notches, coastal caves, and beach deposits represent very good indicators to infer climatically- or tectonically-induced variation of the sea-level trough time. Along the Atlantic coast of Morocco, the raised occurrence of these morphological features was often correlated with the paleo-shorelines formed during the last interglacial period (Marine Isotopic Stage 5, MIS5). However, this area was also characterized by a mid-Holocene highstand (about 6 to 4 ka BP) of isostatic origin. For this reason, it is presently complex to clearly define the ages of the paleo-shorelines in nortwestern Morocco and disentangle between Holocene and last Interglacial sea-level still stands. In addition, the sea-level framework is complicated by the late Quaternary tectonic activity which resulted in variable vertical motions of the coast.

Here we present an updated assessment of the altimetric and chronological variability of the paleo-shorelines along the Morocco coast. In particular, we coupled new data derived from geomorphological and sedimentary analysis performed in the Rabat-Témara area which were compared and contrasted with the already available data along the mid-norther Morocco coast. The results of this analysis provided fresh insights into the altimetric variability of the different RSL stillstands since the Late Pleistocene.

Evidence of sea level changes in Southern Mozambique during the Holocene

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Palaeo sea-level changes have been reconstructed from diatom stratigraphy on sediment cores from southern Mozambique, dated by radiocarbon AMS method on shells and bulk sediments. Two sediment sequences were analysed. One was retrieved in Lake Lúngue located c. 30 km north of Xai Xai municipality and 5 km from Malehice Locality and has an outlet toward the Limpopo River flood-plain on its western side. The other core was collected in Macassa Bay, located in Inhambane Province c. 25 km south from Vilankulos municipality. Bulk dates from Macassa Bay displayed a bottom age of c. 4650 BC (c. 6650 cal yrs BP) while shell dates performed on the gastropod *Mellanoides tuberculatta* from Lake Lúngue indicated that the bottom of the core is dated to AD 740 (1210 cal yrs BP).

In both sequences diatom results are interpreted to represent sea-level and climate proxies. Two periods of high sea-levels stand were identified that occurs at c. 4650-4350 BC (6600-6300 cal yrs BP) and c. 2650 BC-AD 1050 (4600-1000 cal yrs BP) in Macassa Bay. The former period is concordant with the global sea-level transgression during the Holocene Climatic Optimum. The site was under freshwater influences between these two periods c. 4350-2650 BC (6300-4600 cal yrs BP). Terrestrial conditions were established in Macassa Bay probably related to to sea-level lowering, sediment input and organic productivity increase. In Lake Lúngue the bottom of the sequence up to AD 910 (1040 cal yrs BP), followed by non-permanent connection to the open sea from AD 910 – 1130 (1040-1130 cal yrs BP), characterized by sporadic incursions of the sea. Marine influences in Lake Lúngue are inferred to have ceased between AD 1130 (820 cal yrs BP) and AD 1360 (590 cal yrs BP). The sea-levels reconstructions from Macassa Bay and Lake Lúngue are in accordance with sea-level curves from SW African coastline (Compton, 2006), but slows less agreement of records from NE coastline of South Africa (Ramsay & Cooper, 2002). The non-phasing could partially be attributed to dating uncertainties.

Key words:

Sea-level diatoms radiocarbon dating Macassa bay Lake Lúngue

New constraints for an early Holocene relative sea-level lowstand from southwest Norway

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New data from submerged bedrock basins spanning more than 50 km of coastal southwest Norway (between Farsund and Tregde), place new constraints on the age and depth of an early Holocene lowstand. Submarine basin stratigraphy, determined using subbottom echosounder data and sediment cores, includes buried lacustrine facies, documenting sea-level regression to depths of ca. 10 m below modern sea level. New postglacial relative sea-level histories from the region constrain the age of the lowstand to between about 9 and 11 ka BP. Ongoing retrieval of sediment cores, geochronological and paleoenvironmental analyses, and stratigraphic mapping will further delimit the depth and timing of the lowstand in the study area. Of particular interest are regional variations in i) the duration of the lowstand, as well as ii) the rates and onset of the Tapes transgression. New geophysical modelling, utilizing an expanded database of sea-level index points, is aiming to further clarify the precise origins of these sea-level trends, and includes new estimates of the magnitude and uncertainty of glacioisostatic adjustments following the last glaciation. The results provide important new benchmarks for coastal archaeology, Holocene paleoenvironmental change, and geodynamics.

Insights into Holocene relative sea-level changes in the southern North Sea using SLIPs and an improved microfauna-based transfer function

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Detailed reconstructions of relative sea-level (RSL) histories and their controlling mechanisms are crucial in order to manage coastal-protection challenges, especially in light of global warming and rising RSL. This study contributes to unravelling Holocene RSL change on the East Frisian North Sea coast in high resolution with a new approach for the German Bight. For the first time, a RSL transfer function (vertical error: 29.7 cm ~11% of the mean tidal range) based on a combined training set of benthic foraminifers and ostracods from the back-barrier tidal basin of Spiekeroog is applied to the Holocene record of the back-barrier tidal basin of Norderney. A transfer function is an empirically derived equation, which relates the elevation of modern surface samples to the relative species frequency of modern microfaunal associations. If applied to the Holocene record, the palaeo-water depth is determined from the relative species frequency of fossil associations, providing sea-level index points (SLIPs) with a direct relation to the RSL.

The resulting RSL curve for the tidal basin of Norderney shows a deceleration in RSL rise between 6000 and 5000 cal BP. The smallest possible error envelope (~1m) is based on the good suitability of salt-marsh layers between 5000 and 4000 cal BP. The presented RSL curve provides an approach towards the closure of the common data gap of peat-based curves for the southern North Sea related to a lack of basal peats in the youngest age range, and verifies regional differences in glacial isostatic adjustment.

This approach will be applied to further areas of the North Sea, starting with the Shetland Islands, where RSL data and successful reconstructions are barely existing. This will allow to more accurately assess run-up heights of palaeo-tsunamis that are recorded onshore and offshore of the Shetland Islands (NORSEAT Project).

Session 148: Climate-glaciers interactions in mid-latitude mountains

The Little Ice Age over the Western Himalaya, India

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The Little Ice Age (LIA) and the Medieval Warm Period (MWP) are the major climatic episodes of the last millennium. However, the exact timing and duration of these climatic episodes over different continents are spatially varied. The LIA is a period of glacial expansion when temperature significantly dropped in the Northern Hemisphere. However, limited proxy records restrict our understanding to identify the hydrological impact of the LIA over the Himalaya. Here, we investigated a network of sixteen moisture-responsive tree-ring chronologies from Jammu and Kashmir, northwest Himalaya to evaluate the spatial and temporal span of the LIA in the region. The tree-ring-width chronologies of Himalayan cedar and neoza pine were used to develop the annual (previous year October to current year September) precipitation record for the Jammu and Kashmir region. The 635 years (AD 1383-2017) precipitation record revealed three distinct centennial scale phases; early (AD 1383-1650s), middle (AD 1650s-1850s), and late (AD 1850s-2017). Among the three phases, the middle phase reflected stable precipitation with prolonged pluvial conditions, which suggests the LIA influence during AD 1650s-1850s over the western Himalaya. However, the early and late phases of the reconstruction record high-magnitude droughts, which do not endorse the LIA impact over the western Himalaya during these periods. The observed LIA influence was tested using independently developed precipitation, drought, and river flow records of the western Himalaya. The reconstruction skills and its large-scale teleconnections were also explored using the hydrological records from Central Asia. The hydrological records deduced from tree-rings, caves, ice cores, and lakes over the Himalaya and Central Asia are in accordance with identified pluvial LIA conditions over the western Himalaya, while observed high-magnitude droughts in early and late phases do not support that the north-west Himalaya witnessed LIA influence before AD 1650s.

"Weißseesptize glacier (Central Eastern Alps): a 6000 thousand years paleoclimatic and paleoenvironmental reconstruction"

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For a long time, alpine ice core research has focused on a few suitable drilling sites in the Western European Alps, until the discovery of the Ötztal ice man made researchers aware of the millennial-old ice preservation even at lower altitudes glaciers in the Eastern alpine sector. Indeed, despite their highly sensitive mass balance to climate change, glaciers in the Eastern Alps may offer long records and a broad range of proxies, including stable water isotopes and various inorganic and organic impurities, as in the case of the Weißseespitze (WSS) summit ice cap (Central Eastern Alps, 3500 m a.s.l.), where about 6000 years appear locked into about 10 m of ice. Therefore, in March 2019, a group of scientists led by Andrea Fischer carried out a mission on the Weißseespitze glacier to drill two parallel ice cores down to bedrock, and potentially save around 6.7 ± 0.4 ka cal, from a surface probably older than 1963. One of those shallow ice cores was then analyzed at Ca' Foscari (UniVe), extracting levoglucosan, insoluble dust particles and conductivity data through the new CFA system, achieving a high-spatial resolution (down to 1 cm for levoglucosan). In addition, water stable isotopes ($\delta^{18}O$, δD), major ions (Na^+, Cl^-, Br^-, K^+, Mg^{2+}, Ca^{2+}, NO_3^{2-}, SO_4^{2-}, NH_4^+, MSA^-), carboxylic acids (acetic, glycolic, oxalic, malonic, succinic, glutaric), and trace elements (^{7}Li, ^{9}Be, ^{51}V, ^{52}Cr, ^{55}Mn, ^{59}Co, ^{60}Ni, ^{63}Cu, ^{66}Zn, ^{71}Ga, ^{74}As, ^{77}Se, ^{85}Rb, ^{88}Sr, ^{107}Ag, ^{111}Cd, ^{115}In, ^{137}Ba, ^{205}Tl, ^{208}Pb, ^{209}Bi, and ^{238}U) were measured off-line, crucially contributing to the WSS paleoclimatic and paleoenvironmental reconstruction, while providing interesting comparisons with the nearby Mt Ortles ice cores. This huge dataset was then digested through Positive Matrix Factorization (PMF), from which a predominant sea-salt and biomass burning contribution was pointed out (58.5% of the total). Results appeared in-line with the outcomes from the preliminary age model, which would bind the start of the record to the end of the XVII century, though requiring for new constraints to minimize the fit function uncertainties.

Eastern Alpine ice cores and summit soils: Two sides of the same coin telling stories about tipping points?

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Summits which became ice free in recent years are blossoming, demonstrating a quick shift from ice to vegetation cover. While the ice core records in Eastern Alps indicate cooler periods, summit soils might indicate warm periods. Investigation of ice core summit sites exhibited basal ages of millena, with an elevation dependent onset of the reglaciation. If the coexistence of plants and ice as observed today is a very short time effect of rapid warming or if this could be a more persistent feature can be revealed by studying multiple complementary pairs of soil and ice datings.

The ice core from the summit of Weißseespitze (Ötztal Alps, Austria, 3500 m), revealed a glacier cover of the summit which lasted for about the past 5900 years. Close to the ice core site, today the blossoming flowers benefit from older layers of soil, dating between the Holocene Optimum about 7000 years, but also two later periods. The thickness of the soils layers separated by fine silty layers roughly corresponds to lower bog records as Oberfernau (Stubai, Austria).

As blossoming summits have been observed recently also for Jamtalferner (2950m) and Hochkönig (2900 m), and soils seem to be present there also, dating those soils might infer information on past warm periods, once contamination by aeolian sediments and recent roots can be quantified or even excluded.

Post-LIA time-lapse analysis of ice volume changes in the Marmolada Glacier (Dolomites, Italian Alps)

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The Marmolada Glacier is the largest and most extended glacier of the Dolomites. It holds the highest part of the Northern Slope of the Marmolada developing along a large front about 3 km wide. It has been divided into various areas according to its morphology, orography, and ice flow.
The glacier has been studied and systematically measured with scientific criteria since the early years of the last century, also for the interest related to the construction of the hydroelectric basin; its evolution, with some temporal gap, is therefore quite well known. The morphology of the glacier starting from the early ’900 is carefully depicted in topographic maps which have been digitized and are part of a GIS project containing tens of maps, aerial photographs, lidar point clouds and satellite images. The retreat of the glacier and the ice collapse from the front of the Marmolada Glacier occurred in 2022 is analyzed in detail, considering the bedrock morphology obtained by GPR surveys and relating temperature trends to glacier withdrawal.

Ascertaining the response of glacier dynamics to a changing climate since the Little Ice Age (LIA) in the semi-arid region of North-western Himalaya

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The Hindu Kush Himalaya (HKH) has the largest concentration of glaciers outside the Polar regions. Long-term records of glacier fluctuations since the Little Ice age (LIA) are essential to understand the intricacies of glacier-climate interactions and linkages to post-LIA climate warming, and consequences on future meltwater supplies across the HKH region. However, the studies pertaining to the nature of long-term glacier fluctuations since LIA and particularly deglaciation following the LIA maxima (LIA_{max}) are virtually non-existent for the Himalayan region. Such gaps have been tried to be filled up by a multi-data integrated approach (MDIA) which primarily includes the mapping of glacial geomorphological signatures such as moraine stratigraphy and associated absolute chronology, the historical archives (repeat photographs, old topographical maps, published reports), climate proxies (mainly tree rings and lake and lacustrine sediment geochemistry), high-resolution remote sensing data (for palaeo-ice surface reconstruction to ascertain the long-term glacial extent and related volume changes) and extensive field observations in the Chandra-Bhaga valley of North-western Himalaya. The initial result identified three periods of LIA advance during the past millennium: a late Holocene advance around 800–900 CE, a second advance stage around 1300-1600, and a third advance stage during 1800-1900. The study finds a continuous recession trend of glaciers since the post-LIA_{max}. Moreover, the study didn't find any interruption by intermediate phases of advance (at different times) across the studied glaciers. Despite evidence for climatic control over glacier fluctuations, the individual glacier response is likely to have been modulated by glacier topographical (e.g. area, elevation, altitudinal range, slope, and aspect) and surface characteristics (e.g. debris-covered) in the basin. The results show mean equilibrium line altitude (ELA) rise (ΔELA) for all the studied glaciers on a basin scale is 75 m with minimum and maximum ΔELA for the individual glacier of 29 and 149 m respectively. More analyses are being carried out, and the outcomes will be discussed in context, in order to anticipate the future evolution of glaciers across the understudied Himalaya Region.

A paleoclimatic record from the isotopic composition of the Mt Ortles ice cores, Eastern Alps, Italy

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The vast majority of low and mid latitude mountain glaciers have been quickly retreating over the last decades, lowering the possibility of the preservation of climatic records in their ice. While several drillings have been carried out in the Alps for the last 50 years, very few attempts to obtain temperature reconstructions from the isotopic records of Alpine cores have been successful.
The presence of a dense network of meteorological stations, which have been operating for over two centuries, as well as the proximity to a densely populated and developed area, make the Alpine glaciers a unique spot to obtain paleoenvironmental and paleoclimatic information through ice coring.
In autumn 2011, four cores were drilled on the Alto dell'Ortles glacier (3859 m a.s.l.), three down to bedrock at an approximate depth of 75 m. The glacier is currently transitioning from a cold to a temperate state: the firn can reach the pressure melting point, while the ice below 30 m of depth is still cold. Carbon-14 determination on Water Insoluble Organic Carbon (WIOC) supported a time scale dating back to ~7000 years before present, making the Ortles paleoclimatic record one of the very few in the Alps covering most of the Holocene.
A refinement of the Ortles chronology was obtained through a novel approach: here we compare the $d^{18}O$ records from core #1, #2 and #3, based on the revised chronology, to the instrumental temperature series since XVIII century, using different low-pass gaussian filters with increasing sigma values. The linear regression between temperature and isotopic data shows an increasing R^2 and slope when increasing the sigma of the low-pass gaussian filter. While few periods are characterized by opposing trends, the overall agreement between temperature and $d^{18}O$ is robust.

Through the ice of a melting glacier: chronological approaches and land use reconstruction from an Adamello glacier core (Italian Alps)

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Glacier ice cores from mid latitudes are capable of retaining important information on past climate and anthropic activities at high time resolution. However, Alpine glaciers are particularly sensitive to the current climate warming, which is seriously compromising their persistence. The present extensive ablation and the potential vanishing of these glaciers are leading to the loss of unique climatic and environmental archives. Here, we present chronological and palynological results from a 46 m deep ice core extracted from the Adamello Glacier (3100 m a.s.l.), the deepest and most extended glacier in Italy. Integrating the results of radionuclides ^{210}Pb and ^{137}Cs with annual layer counting derived from pollen and refractory black carbon concentrations we were able to obtain a reliable timescale. Our outcome indicates that the glacier surface is about 20 years older than the drilling date of 2016, and that the 46 m ice core reaches back to around 1944. Additionally, for the period of 1995–2016 the mass balance at the drilling site (former accumulation zone) decreased on average of about 1 m w.e. a^{-1} compared to the period 1963–1986. The palynological record obtained from the core has been employed to reconstruct past land use changes in the Adamello area. Pollen inferred vegetation trends have been calculated using pollen indicators obtained from a database of vegetation-plot observations, and the reliability of these trends is evaluated by comparison with spatially explicit tendencies reconstructed according to a time-series of land-cover maps. We found that the Adamello pollen record well represents the natural vegetation types as the temperate and the riverine forests, as well as the anthropic vegetation (crops and alien species) and that from the 1980s a thermophilisation took place.

ADA 270: palaeoclimate evolution of the past centuries from the Adamello Glacier

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Alpine glaciers are sensitive natural archives for reconstructing past climate and environments through time, in and around the glaciers.
The Adamello Glacier, located in the Central Italian Alps, has an extension of ca 14,35 km^2 (2020) between 2560 - 3420 m asl, and it is the deepest Italian glacier. The ELA (Equilibrium Line Altitude) is located at ca 3000 m asl. The glacier was chosen for a coring campaign that took place in 2021 and led to the recovery of a 224 m ice core (ADA 270). Preliminary estimate for the age of the core bottom could be around 1000 years ago; the core would span the time interval from around the Medieval Warm period to today.
The core, stored at the EUROCOLD facilities at the University of Milano-Bicocca (https://eurocold.disat.unimib.it), is being studied at subannual resolution by means of a multiproxy approach that includes oxygen and deuterium stable isotopes, black carbon, dust, diatoms and microbotanical content (pollen and spores), plus the measurements of the radionuclides ^{210}Pb and ^{137}Cs.
The pollen analysis of this core is oriented towards the reconstruction of regional past ecosystems. The samples so far analyzed document the presence and good preservation of palynomorphs. Seasonality of the pollen signal seems to be preserved, with *Corylus* and other taxa being the spring signal while *Pinus*, *Ostrya* and many more taxa being the summer signal of the flowering season. Different species of diatoms have been also observed. The results of the first few months of research will be presented and compared to the visual stratigraphy of the core and the hyperspectral analyses carried out on the same core.
The main targets of the research will be: (i) documenting the effects of anthropic activities on natural environments during the Industrial Period; (ii) the impact of World War I on the alpine environment; numerous battles were fought between the Italian and the Austro-Hungarian Armies on the Adamello Massif; (iii) climate and ecosystem reconstructions during the Little Ice Age and the Medieval Warm Period.

Session 152: Archaeological cave sediments: a key to decipher past human behavior and palaeoclimatic change

Site formation processes at two rock-shelter sites of the Pleistocene-Holocene transition in Kyrgyzstan (Central Asia)

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At the foothills of the Alay mountain range, in the southern margin of the Fergana Valley, Obishir-5 and Obishir-1 are two archaeological sites of the Pleistocene-Holocene transition bearing archaeological material of the Obishirian culture. Additionally, the sites' importance has increased thanks to recent studies on the faunal remains which shed light on the Neolithization process in Kyrgyzstan and more ambitiously in Central Asia. In particular, the sites are located in front of two rock-shelters at the toe of largely karstified limestone cliffs in an high-elevated and arid intermontane basin of the southwestern Kyrgyzstan. Geoarchaeological investigations have been carried out to give geologic context to the archaeological record and for a better understanding of the site formation processes and post-depositional disturbances. A multi-aspect approach has been designed consisting of sedimentological, micromorphological, and geochemical analyses for the study of the sedimentary material, coupled with chronometric dating and the study of faunal assemblages, as well as artifact spatial distribution analyses. The information retrieved allowed to reconstruct the depositional history, traces of human-related activities, and paleoenvironment reconstructions at both sites. Importantly, the sites are both embedded in cliff-related talus deposits, but they faced slightly differing processes which were recorded throughout the sedimentary sequences. Confronting the Quaternary sequences at the two Obishir sites, the "human factor" emerged to be an important element in the accumulation, erosion and disturbance of the stratigraphic sequences. In particular, the adoption of micromorphological methods resulted to be a powerful tool in discerning differences amongst the two considered sites.

Evaluating the potential of limestone as a proxy for archaeological fire at Pech de l'Azé IV (France)

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Archaeological sediments are a valuable source of information to infer past human activities related to fire. Over the past few decades, increasing research concerning the effects of fire on the archaeological record has shown that sediments exposed to heat are irreversibly altered and can contribute to answering key questions related to burning events, such as the spatial distribution of combustion features, the intensity and frequency of heating, and the integrity of thermally altered deposits. However, comparatively few studies have dealt with the thermal behaviour of specific inorganic constituents (minerals, rocks) in archaeological sediments. In this work, we present the results of a laboratory-based experiment designed to examine how heat affects limestone, one of the major components of cave deposits. This experiment was conducted on micro-contextualized samples from Layer 8 of the Middle Paleolithic cave site of Pech de l'Azé IV (Dordogne, SW France), where the use of fire by Neanderthals is well documented. Under a set of controlled conditions, experimental samples were subjected to different temperatures and subsequent alterations were recorded using a variety of macro- and micro-scale techniques, including colourimetry, micro-FTIR, petrographic microscopy, and SEM-EDS analysis. By systematically documenting and evaluating the archaeological relevance of these alterations, we aimed to create a baseline reference against which archaeological sediments could be compared and thermally classified. Our results indicate that some of the changes produced, especially those associated with the colour and the microstructure of the samples, can be used to distinguish unheated (<200 ºC) from heated (>400 ºC) limestone with relatively high confidence, and that limestone exposed to temperatures above 700 ºC becomes friable and may be nearly impossible to identify in archaeological settings. In combination with other well-established proxies, we believe that the approach hereby proposed is suitable for the recognition of ancient fire in caves and other carbonate-rich environments.

Sandstone cave sediments: a geoarchaeological assessment

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The site formation processes of cave and rockshelter archaeological sites are the subject of many geoarchaeological studies. Karstic cave deposits have been intensively studied, while similar contexts in quartzitic bedrocks (sandstone and quartzite) have received less attention. In this talk, I review common aspects of the formation of quartzitic caves through an extensive geoarchaeological literature review. I conduct a comparative analysis of sites around the world based on aspects including the climatic setting, bedrock mineralogy, site preservation (charcoal, bone), as well as geoarchaeological methods applied. In addition, I review a variety of geoarchaeological techniques used to conduct geoarchaeological studies on quartzitic caves. Standard bulk sediment analyses like granulometry, pH, and Loss on Ignition are often overlooked although they can provide important insights into the formation processes. To fully assess the depositional and post- depositional processes, micromorphological analysis needs to be conducted. My analysis demonstrates preservation conditions of the sites appear primarily affected by the moisture content of the sediments which, in turn, is often related to the bedrock hydraulics of the rockshelter. Finally, I suggest a workflow template for researchers (both archaeologists and geoarchaeologists) working on sandstone and quartzite rockshelter excavations.

A cautionary tale: Testing the chronology of Zambian cave site stratigraphies using amino acid geochronologies.

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The South-Central African region is increasingly thought to have played an important role within mammalian (including hominin) evolution during the Quaternary. Archaeologically, the region has yielded the Kabwe cranium (*Homo heidelbergensis* (*rhodesiensis*)), changing tool technologies and early pigment use (~265 ka). Ecologically, the region's current habitat is primarily dryland savannah, but there is evidence that during the Quaternary, there was an extensive palaeo-wetland, encompassing the Okavango delta, the Makgadikgadi pan and the Zambezi and Kafue rivers. This wetland would have provided both a migratory corridor between Southern and Eastern Africa, and an ideal environment for hominin habitation in its own right.

In Zambia, fossil preservation at cave sites such as Twin Rivers and Mumbwa Caves provide rare opportunities to study the region's archaeology and palaeoenvironments. Dating is crucial to understanding these sites individually, and especially when relating them to the wider evolutionary patterns; however the chronology of the region is not well understood.

Cave depositional histories are notoriously complex and can provide an especially challenging environment to date. Here we propose the use of amino acid geochronology, using the relative dating information from intra-crystalline protein degradation (IcPD) in fossils, as a tool for testing the chronology of cave site stratigraphies. IcPD exploits the time-dependent breakdown of proteins (racemisation, hydrolysis and degradation of amino acids) contained within biominerals (e.g. mollusc shell and teeth). Targeting the intra-crystalline fraction of protein minimises the effects of contamination, leaching and other impacts of the depositional environment, and provides direct dates on relevant fauna, on Pleistocene timescales.

Here we discuss the IcPD analysis of mammalian tooth enamel from 2 cave sites in Zambia, with more general implications for the reliability of interpreting associated archaeological and palaeoenvironmental material based on cave site stratigraphies.

Early Neanderthal frequentation in the Mediterranean: environments and processes from the sedimentary archive of the "Terre Rosse" at Grotta Romanelli (Apulia, Southern Italy).

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Grotta Romanelli (Apulia, Southern Italy) is a key site in the Mediterranean Quaternary, preserving a unique sedimentary and geomorphological archive which encompasses the last 350 ka BP. The litho-, morpho- and chronostratigraphical setting of the infilling deposit has been recently reassessed, placing the oldest human frequentation of the cave between MIS 9 and MIS 7, roughly between 340 and 240 ka, therefore embracing Glacial and Interglacial cycles. Previously, the sediments in Grotta Romanelli were attributed to the Last Interglacial-Glacial cycle (124-20 ka).

The cave has provided important evidence of human and animal frequentation across the whole filling succession and ISU3 (also known as "Terre Rosse") yields hundreds of limestone tools referred to Middle Palaeolithic and thousands of vertebrate faunal remains. ISU3 is made of thinly layered planarly or cross-bedded silts, clays and sands typical of low-energy run off processes which affected deposits of aeolian origin and colluviated soil features washed into the cave and derived from the erosion of the leached, argillic soils covering the surrounding landscape. The age of ISU3 was constrained between ca. 200 ka and 110 ka by under- and overlying U/Th dates on speleothems although palaeobotanic evidence suggests an early Late Pleistocene age (MIS5).

Here, we present new sedimentological and micromorphological analyses, luminescence and U/Th ages coupled with geochemical, mineralogical and paleomagnetic investigations. These results offer new palaeoenvironmental insights about the context where these early Neanderthals lived in the southern Mediterranean Europe.

Reconsidering Mid-Upper Pleistocene natural and anthropogenic cave sediments at the Balzi Rossi archaeological area (Liguria, Northern Italy)

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In the Pleistocene, the Mediterranean hosted a variety of environmental settings, including ecological refugia, and played a special role as hub for human dispersal across Europe. Western Liguria (Northern Italy), and especially the Balzi Rossi archaeological area, represent a hot spot to investigate how human populations have responded to Pleistocene environmental and sea-level variations. Local natural and anthropogenic cave sequences have been excavated since the XIX century, disclosing an extremely rich archaeological panorama. Unfortunately, the geological processes in charge of the formation of such deposits have been only occasionally considered. To avoid this lack of information, the SPHeritage Project (MUR grant: FIRS2019_00040, P.I.: M. Pappalardo) is investigating the Balzi Rossi area, with an interdisciplinary and multidisciplinary perspective, the human-environment interaction over the last 400,000 years, including geochronology, micromorphology, and other archaeological sciences. As most of the local archaeological sequences were removed at the beginning of the last century, we are combining the analyses of strips of anthropogenic sediments preserved in museums and remnants still preserved inside the rock shelters of the archaeological complex. Our geomorphological survey identified new sedimentary sequences preserving information on relative sea level changes, better constraining the time and steps of climate change, sea-level oscillations, and human settlements. The micromorphological investigation at the Cave of the Prince of Monaco highlighted that the sequences formed thanks to long-lasting activity of a freshwater spring that contributed to the formation (during the Middle Pleistocene) of beach deposits alternating with continental calcareous tufa showing different sedimentary facies and entombing evidence of human attendance of the site. Climate and sea-level changes modulated the shift from calcareous tufa precipitation to beach sediments formation. The comparison between open-air, natural sequences and those preserved at the ex-Casinò site allowed the identification of composite sequences alternating beach deposit, weathered into a red soil during MIS5e, then reworked and buried by slope sediments in the Upper Pleistocene, when the area was exploited by humans. Our results allow us to discuss a fresh interpretation of the formative processes and chronology of the major anthropogenic sequences preserved at the Balzi Rossi and the correlation between natural and anthropogenic evidence.

Contextualising the Pleistocene archaeological record of Southeast Asia: using a geoarchaeological approach

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Southeast Asia is a critically important region to our understanding of Pleistocene hominin evolution and demographics. The Pleistocene fossil and archaeological record of Southeast Asia is, however, patchy, often formed of elements that are small, scant, poorly preserved, and recovered from complex sedimentary environments. Nevertheless, such finds hold immense potential to rewrite what we know about the evolution of our species, our co-existing hominin ancestors, and the environments they adapted to and ultimately thrive within.

Geoarchaeology borrows concepts and methods from a range of Earth Sciences to help understand and interpret the archaeological and fossil record. Geoarchaeological analyses are gradually becoming more routine in their application to human evolutionary studies in some regions of the world, to both contextualise archaeological and fossil material, as well as providing an independent environmental proxy record that can document changes in site and catchment environment. Using high resolution geoarchaeological data it has been shown that critical fossils and artefacts can be published with highly resolved contextual data that increases confidence in the veracity of a given study. This is vital in Southeast Asia where tropical conditions can hamper our understanding of the archaeological and fossil record because poorly understood geomorphic processes that drive sediment diagenesis and accelerate taphonomic processes that might significantly affect fossils and artefacts.

Here I will: i) showcase the potential for a range of geoarchaeological analyses to provide critical contextual information for fossil and archaeology from the region (thus circumventing common issues such as inadequate stratigraphic—and geochronological—control); ii) evaluate how effectively such an approach is being used—or not—in the region (where tropical geomorphological processes are less well understood than in other major regions of human evolutionary analyses, such as Europe and Africa); and iii) look to the future to examine how we might better incorporate a geoarchaeological framework (including emerging and state-of-the-art analytical techniques) into all archaeological and palaeontological projects from the earliest stage.

Session 154: Quaternary research in South America: paleoclimate, tectonic, volcanic and surface processes

The Parana Delta (Argentina): a high-resolution record of the Holocene

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The Parana Delta of the Rio de la Plata estuary borders some of the most populated areas of South America and builds from one of the ten largest rivers in the world, yet still is yielding new insights. While the lower part of the delta has received much attention, the upper part is only recently studied. Analysis of neotectonics, wave action, and sediment supply of this segment permits a more holistic story of delta evolution and reveals some unique aspects of evolution for this part of the South Atlantic coast. A depositional and chronological model of delta landforms and OSL and C14 dates is here presented. The complex history of the delta starts at sea-level highstand before 8,000 yr BP and lasting to 6,500 yr BP (+6.5 masl), continues through a falling stage at 6,500 yr BP to 4,500 yr BP (+5 masl), and levels into a lowstand (+2 masl) from 4,500 yr BP to Present. The initial highstand delta was fluvial-dominated, but altered to a mixed wave-dominated delta by ~8000 yr BP. The fluvial highstand delta predates the oldest beach cheniers of 8,100 yr BP, previously thought to be ca. 6,300 yr BP, and postdates the underlying transgressive muds at 9,300 yr BP. After a period of wave-delta propagation, relative sea-level began to fall and forced downstepping of the shoreface producing a falling stage systems tract. During this time, the waves refracted around intraestuary islands which altered the trajectory of chenier building. Starting ~2200 yr BP, the delta returned to a fluvial dominated delta system, which remains the case until today. The current delta has aggraded with sea-level rise since ca.1,000 yr BP. At well over 8,000 yr BP the South American shoreline here hit relative sea-level maximum relatively early, probably because of uplift, making the Parana a candidate for the oldest regressive Holocene delta in the world. At <37 Billion cubic meters the highstand delta volume is surprisingly small for a river this size. Uplift continued, forcing relative sea-level drop and downlap of a falling stage over the maximum flooding surface through middle Holocene.

Recent trenching studies on the major Algeciras fault in its crossing of the Eastern Cordillera of Colombia

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The major Algeciras Fault (AF), belonging to the Colombian Algeciras Fault System (AFS), is part of a continent-scale dextral system, originally named as the Eastern Frontal Fault System, extending for 1900 km from Ecuador to Venezuela, which splits the North Andean Sliver from South America in a process of NNE-directed tectonic escape. To assess the seismogenic potential of AF, which is a highly potential seismic threat to Bogotá, the *Geological Survey of Colombia (SGC)* –after carefully mapping the AFS at its oblique crossing of the Eastern Cordillera, along the Garzón Massif northwestern border, on the basis of Quaternary landforms of tectonic activity-, has excavated 4 paleoseismic trenches across its trace in the Huila Department: two in the Algeciras pull-apart basin in 2016 (Lagunillas, Santa Elena) and two to NE of Garzón in 2021 (Potrerillos, Miraflores School), 50 km apart to the southwest. Despite the evaluation of the Santa Elena trench is still pending, the Lagunillas trench, excavated across the basin shortcut strand, attests to seven Holocene Mw 7.0+ earthquakes, with an average recurrence of 1300-1400 years. In turn, both trenches at Miraflores were excavated across both strands of a restraining stepover. In fact, the Miraflores School trench seems to assess the same AF Algeciras-Tres Esquinas segment as the Lagunillas. This appears supported by that both trenches (Lagunillas and Miraflores School) disclose the same latest February 09^{th}, 1967 event. Besides, the AF slip rate deduced from the total deformation recorded at the Lagunillas site is about 0.7-0.8 mm/a, which is very similar to that of Miraflores (1.0 mm/a). In addition, the recurrence interval at Miraflores School is of ~ 1500 years, from the last three events. Instead, the Potrerillos trench, opened across a fault trench, bounded by two normal-dextral faults 10m apart, reveals that the SW-extending Garzón segment recurs much faster, at about 500-600 years, with latest events occurring roughly at 700, 1300 and 1800 AD. The trench-derived slip-rate of this segment is 4.0 ± 0.4 mm/a. Last, this segment seems responsible for the historical November 16^{th}, 1827 Mw 7.1 earthquake, which would support the independent behaviour of both AF segments.

Late Quaternary fluvial deposits in the Colombian Andes foothills: insights from tectonic and climate drivers

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Alluvial deposits are well developed and preserved in the Eastern Cordillera of Colombia's foothills as potential archives of tectonic uplift and climatic variations in a poorly studied tropical region. The main aim of this research is to investigate the evolution of the alluvial deposits in the upper Guaviare River basin in southern Colombia. We mapped landforms by visually interpreting the Landsat images and Copernicus digital elevation model (DEM; GLO-30) and used optically stimulated luminescence (OSL) dating in quartz grains to estimate burial ages. Our results show that most landforms were formed by alluvial and fluvial fans with distinct lobes, which are preserved as several terrace levels up to 120 m higher than the modern floodplain. Clast-supported massive gravels dominate the sedimentary facies of these alluvial and fluvial fans with rare and thin layers of coarse-grained sandstones. The current floodplains are related with braided to sinuous channels from up to downstream; gravels dominate their sedimentary facies, but sand layers are frequent. Prelaminar OSL ages indicate that the highest terrace level is not older than 100-150 ka, suggesting impressive high incision rates during the late Pleistocene and Holocene. Therefore, new OSL ages (in progress) will allow us to estimate the burial ages of the mapped landforms and give new insights into the timing and driving factors related to changes in the fluvial dynamic and landscape evolution of the tropical Andean piedmont. (FAPESP grant #2020/11047-1)

The glacier-climate history of Cordillera Pariacacá and Cordillera Huaytapallana, central Peruvian Andes, from the Late Pleistocene to Holocene

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Peruvian glaciers are retreating steadily and rapidly. Cosmogenic exposure dating of moraines aids understanding of how glaciers have responded to past climate changes. In turn, this provides insights into how these vital meltwater resources may behave under predicted climate change. Cordillera Pariacacá and Cordillera Huaytapallana (~11.5 ºS), provide meltwater to a population of 11 million in Lima and ~500,000 in Huancayo respectively. No chronologies, however, exist for their moraine sequences and associated ice dynamics. This study provides the first glacial geochronology based on ^{10}Be exposure ages of moraines that likely span from the Last Glacial Maximum to the late Holocene.

The modern Peruvian climate and glacial dynamics have been linked to variations in Pacific sea surface temperatures, the InterTropical Convergence Zone and South American Summer Monsoon. The climate is also modulated by the Andean Mountain chain, which acts as a topographical barrier to advancing cold fronts and low tropospheric flows causing a rain shadow on its western flank. The climate of western Andes, where Pariacacá is located, is influenced by the Pacific Ocean and is arid. Conversely, the eastern Andes, where Huaytapallana is situated (~100 km east of Pariacacá), are more influenced by Atlantic Ocean conditions and are humid. Palaeoclimate studies from across Peru have inferred linkages between the Andean Holocene climate to both Atlantic and Pacific conditions. Data from this study, which compares glacial ages from Pariacacá and Huaytapallana, will help constrain the ocean and atmospheric controls on glacier surface mass balance in the central eastern and western Andes, how the controls differ between the two sides of the mountain chain and how they have developed since the Last Glacial Maximum.

In 2022 a field campaign was undertaken involving the universities of Aberdeen and Complutense de Madrid, and the Instituto Geológico, Minero y Metalúrgico Peru. 66 granitic and gneissic rock samples were collected from 14 moraines in the Huaytapallana and Pariacacá ranges. ^{10}Be cosmogenic dating of moraines is currently being undertaken at the Australian Nuclear Science and Technology Organisation. Results of this analysis along with palaeoglacier reconstructions for Pariacacá and Huaytapallana and comparisons to palaeoclimate will be presented.

Climatic and anthropogenic signals in the last 2000 years using diatoms and XRF in lake sediments from Cordillera Vilcanota in the central Andes

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Lake Yanacocha is a tarn formation surrounding the Quelccaya Ice Cap and is considered a non-glacially fed, shallow and polymictic elevated Lake located in Cordillera Vilcanota. The results from diatoms analysis showed a steady population of small fragilaroids such as Staurosira venter and aulacoseiras alpigena and válida that reached maximum values of around 40 per cent relative abundance. The diatoms doubled their concentration and accumulation rates in the last 1000 years. The Diatoms Concentration and Staurosira venter had similar increasing trends and opposite to aulacoseiras. The clustering analysis identified five zones where zone 4 showed the lowest value of diatoms accumulation rate and richness species. The increase of clastic flux in Zone 2 might be driven by pre-incan anthropogenic activities including mining and agriculture. The maximum values of Fe registered in the XRF analysis in Zone 2 might have limited the production of aulacoseiras, due to their sensitivity to high metal concentrations, in addition to arid conditions. Processes of re-suspension of the sediments and wind-blown transport of diatoms valves from surrounding lakes, can be also considered as other possible causes for the rise of diatoms concentration, that decreased in Zone 1. The canonical analysis would suggest that most of the carbon content in the lake would come from littoral zones and surrounding vegetation composed mainly by mosses.

How did the 4.2 ka BP Cerro Blanco eruption impact the hunter-gatherer community of the Yocavil valley, NW Argentina?

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Due to the intense anthropization of the landscape or the scarce research efforts on prehistoric populations of hunter-gatherers in the intermontane valleys of the Andes, occupation sites have been found on very few occasions. However, new perspectives in the Abra del Toro rock shelter in the Yocavil Valley (Catamarca province, Argentina) have opened up from recent and ongoing excavations. The stratigraphic record of the rock shelter shows a 1-m-thick volcanic ash deposit formed by aeolian transport from primary outer ashfall deposits. Geomorphological and sedimentological context, texture, glass and mineral content, whole-rock chemical composition, and radiocarbon dating prove that the tephra was derived from the 4.2 ka BP eruption of the Cerro Blanco Volcanic Complex in southern Puna (NW Argentina). This volcanic eruption is the largest documented in the world in the last five thousand years and covered the surroundings of the archaeological site with an ash layer of approximately 1 meter thick. The stratigraphic sequence of the Abra del Toro rock shelter allows us to hypothesize that there were three main occupational moments: two hunter-gatherer moments, separated by the record of the large volcanic eruption, and a subsequent agro-pottery period (Carbonelli et al. 2022. J. Archaeol. Sci. Rep. 45, 103629). The rock shelter after the eruption remained in the memory of the hunter-gatherer groups. Good visibility, accessibility, and proximity to water were attributes of this space that made it possible for it to be re-occupied after the eruptive event. Our next objective is to reconstruct, using proxy analysis, how the paleoenvironment was in the intermontane valleys before and after the eruption. The evidence of this Mid-Holocene catastrophic volcanic event in the Abra del Toro rock shelter opens the possibility of knowing its impact on the contemporary hunter-gatherer community and drawing conclusions for similar future volcanic crises.

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Late Pleistocene-Holocene paleoenvironments and paleoclimate of a subtropical distributive fluvial system at the eastern Andean piedmont of South America

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The eastern Andean piedmont of southern South America shows several distributive fluvial systems (DFS) formed by antecedent rivers that carry seasonal meltwater from the Andes Cordillera. One of them is formed by the Atuel and Diamante rivers after crossing the San Rafael tectonic block in deep canyons. Ongoing projects are studying the landscape and deposits of this DFS to reconstruct the late Quaternary landscape evolution, provide paleoclimatic inferences, and improve DFS facies models. Methodology includes geomorphologic mapping by remote sensing, field survey, facies analysis of pedosedimentary successions, coring and multiproxy analysis of wetlands, luminescence and AMS chronology. The fluvial dynamics is closely related to aeolian processes as the Atuel-Diamante DFS is under semiarid condition (rain shadow of the Andes Cordillera). The megafan is bounded by dunefields, and the fluvial landforms and deposits are modified and reworked by wind activity. Today, the Atuel-Diamante DFS is a 'misfit' fluvial system due to current interglacial conditions and anthropic intervention on the drainage network. In 1886 the Diamante river waters were artificially diverted to the east, later, in the last 70 years, hydroelectric power dams affected the fluvial regime of their lower basins. Also, the proximal part of the DFS was turned into an agricultural irrigated oasis, by introducing fluvial networks to supply water for irrigation, and soils became strongly salinized. Several landscape features reveal variable geomorphological and climatic conditions in the late Pleistocene-Holocene, like channel incision and fill terraces, wider paleochannels than present channels, a profuse aeolian cover over most the DFS, among others. The chronology shows a late Pleistocene-early Holocene record in an upper-most, 8 m thick, fluvial terrace, suggesting important fluvial aggradation during the last glacial termination and a significant change in the system with extensive incision at the early-mid Holocene. OSL ages show late Pleistocene dune formation and successive stages of dune building in the Holocene. These are associated with fluvial channels and surfaces formed and successively abandoned throughout the Holocene. Although the sand dunes are currently well-vegetated, our record shows that Holocene climate fluctuations have been sufficient to change the hydrological balance, activating sand dunes and diminishing river discharges.

Assessing hazardous faults in South America through collaborative networking

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The prehistoric displacement record of seismogenic faults constitutes a primary input layer for seismic hazard assessment (SHA). This is particularly relevant for areas where the recurrence interval of destructive earthquakes is larger than the time coverage provided by the seismic catalog. Destructive earthquakes onshore South America have occurred along faults whose seismogenic capability is known or suspected. Capital towns, fast-growing urban areas, and critical facilities settled nearby hazardous faults, underscore the significance of understanding the fault-related hazard. However, parametric data of many seismogenic faults in South America do not always illuminate their seismic capability, as some key parameters required for SHA are either unknown, not suitably surveyed, or exhibit significant discrepancies among themselves. The South America Risk Assessment project helped to update and upgrade previous compilation efforts under a network of local experts, with the aim of incorporating hazardous faults in an open-access seismic hazard source model for South America. Although regional data harmonization still needs to be improved, this effort allowed the integration under uniform standards of nearly 1600 Quaternary-active structures in a GIS-supported platform. Relevant fault parameters as to SHA, such as geometry, kinematics, and activity rate have been incorporated whenever possible. There is plenty of room and good perspectives in this field to contribute with sound data to issues of social impact and regional interest.

Morphodynamic analysis of fluvial megafans of the Southern Chaco plain, Andean foreland basin

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Lowland areas of South America provide a natural laboratory for the research of large fluvial quaternary systems. The Chaco plain (ca. 840,000 km^2) represents the most extensive depositional system of the Central Andean foreland basin. This is an ideal tectono-geomorphic setting for generating some of the largest fluvial megafans of the Earth. Chaco megafans are under a humid tropical-subtropical climate and cover large remote and difficult-to-access areas. Their formative rivers, with a downstream decrease in discharge, are mainly connected through the Paraguay-Paraná axial fluvial system. This presentation focuses on the process-based understanding of the Chaco coalescent active megafans in Argentina (22°–31°S; Pilcomayo, Bermejo, Salado-Juramento and Dulce distributive fluvial systems, DFSs). Geomorphological analysis from regional to local scales mainly from remote-sensing data coupled with field and laboratory datasets (stratigraphy and sedimentology) provides new insights into the Quaternary dynamics of these multi-scale dispersal systems. Chaco megafans are particularly sensitive to climate forcing. Significant seasonal fluctuations in the discharge of their formative rivers through the influence of the South American Summer Monsoon were registered. Also, the high sediment input from their Andean catchments, the short-term sedimentation and channel avulsions to adjacent overbank areas are dominant in the construction of these mega-landforms. The required horizontal accommodation space and gradient for their development are closely related to the foreland basin tectonic configuration. Both climate and neotectonics, influence the spatial and temporal pattern of aggradation on these megafans. Highly dynamic fluvial processes dominated during the Upper Pleistocene. The sub-environment complexity along each megafan, deduced from an arrangement of landforms and stratigraphical data, is related to the avulsive behaviour. A partial avulsion is a dominant process in middle-distal Chaco megafan settings, with crevasse and terminal splays formation and overbank sedimentation. Distal zones are dominated by floodplain deposits, with isolated channel-fill bodies. Terminal splay sand sheets (aggradational lobes) covering mud-flat deposits are typical. Extensive floodplain-filling crevasse splays generate in the downstream part of the active river belt of megafans. Large wetlands dominate in distal reaches. A comparison between the Chaco DFSs and the fluvial megafans developed in the dry Central Andean piedmont is also presented.

Refining the chronology of Lujanian and Bonarian Stages

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The late Pleistocene to Holocene sedimentary deposits in the Pampean Region of Argentina has traditionally been assigned to different stratotypes established more than a century ago by Ameghino (1879), the Lujanian, and Bonaerian. These Stages/Ages have been used as reference timescales for Argentina and other South American fossil sites. Nonetheless, there seems to be no consensus about the exact age and the litho- and biostratigraphic correlations of the Pleistocene units of the several sedimentary basins in the Chacopampean Plain geological province. This situation is also linked to the progressive change of geological time and its divisions, with the diversity of nomenclatures and the dual classification of deposits based on the content of fossils and lithological characteristics.

In order to further chronologically constrain the transition between Lujanian and Bonaerian, we have recently employed Electron spin resonance (ESR), U-series, and Optically Stimulated Luminescence (OSL) methods to date and tentatively correlate a series of localities in different basins in the northern (San Pedro,) and southern (Salto de Piedra and Cascada de Paleolama) Buenos Aires Provinces. These preliminary results may be used to compare these two regions, different formations and timescale traditionally used in Argentina that will extend to other basins in the Chacopampean Plain geological province.

Holocene environmental evolution of the Chile Chico Meseta based on lacustrine sedimentary records, Central Patagonia, Chile.

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In order to assess the paleoenvironmental and climatic variabilities of Central Patagonia throughout the Holocene, a 3 m-long composite sediment record was recovered from one of the lakes (46,716º S, 71,844º W) of the Chile Chico Meseta (CCM). Owing to its altitude (~1000 m a.s.l.) and location relative to the Jeinimeni Range (JR), this volcanic plateau offers a unique setting to constrain glacier responses and related environmental dynamics.

Based on five radiocarbon dates, an age-depth model provides time control. This is supported by a fall-out tephra layer corresponding to the well-documented Hudson-H1 eruption (~8500 cal yr BP). Down core multi-element X-ray fluorescence scanning, loss on ignition (LOI), magnetic susceptibility, biogenic silica (BiSi) and grainsize-analyses were carried out. The elements Ca and Ti, relating to the basalts that form the plateau, as well as magnetic susceptibility and granulometry are interpreted as proxies for terrigenous input, whereas the incoherent to coherent radiation ratio (XRF proxy for organic matter), LOI and BiSi are considered as indicators for lacustrine productivity.

Our analytical results show that lacustrine sedimentation spans at least the last ~10,200 cal yr BP, indicating a minimum age for the onset of ice-free conditions and westward retreat of the JR glaciers from the CCM. Between 10,200 and 1000 cal yr BP, sediment proxies exhibit a general increment in minerogenic components, which is particularly pronounced between 5200 and 4500 cal yr BP. In contrast, the concentration of organic matter decreases. We attribute this major shift in sediment composition to an increase in allochthonous detrital transfer from surrounding rocks caused by intensified runoff and/or accelerated ice degradation. In combination with previous work on the moraine chronology from Central and South Patagonia, our outcomes suggest a relationship to the termination of the Middle Holocene glacier high-stand. Around ~1000 cal yr BP autochthonous sedimentation starts to increase again in the lake basin. Whether this shift back to a higher lacustrine productivity is related to local drivers or to regional recent cooling periods has yet to be addressed by upcoming studies.

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Glacier, vegetation, fire-regime, and climate evolution in central-west Tierra del Fuego (~54°s) since local ice-free conditions

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By virtue of its position adjacent to the Drake Passage, Tierra del Fuego allows examining the vegetation and environmental history of the southernmost continental landmass outside Antarctica, and the evolution of the Southern Westerly Winds-Southern Ocean coupled system since the Last Glacial Maximum (LGM). We studied lake sediment cores from Lago Charquito, a small closed-basin lake in central-west Tierra del Fuego with a continuous record since ~17.2 ka. Ice-free conditions at the site imply a ~70 km retreat of the Bahía Inútil glacier lobe from its LGM position along a ~800-year interval, a trend that continued until its disappearance ~100 km upstream, ~700 years later. Our palynological data show an open landscape dominated by cold-tolerant shrubs and herbs between ~17.2-12.8 ka, with increases in precipitation of westerly origin at ~16.3 ka, ~14.7 ka, ~12.8 ka, between ~8.7-6.9 ka, and at ~5.7 ka. Warming at ~12.8 ka initiated an abrupt afforestation trend that stalled during the early Holocene (~12-8.7 ka) owing to a precipitation decline or enhanced rainfall variability and wildfires, and later resumed in response to stronger westerlies. We hypothesize that sparse *Nothofagus* populations inhabited the periphery of the Patagonian Ice Sheet (PIS) during the LGM and migrated toward the Andes contemporaneous with glacier recession as temperature rose during the Last Glacial Termination (T1). Besides establishing topographic and climatic barriers for land biota, the Patagonian Ice Sheet enabled corridors that permitted the connectivity of cold-tolerant hygrophilous plant populations along a humid fringe adjacent to its land-based perimeter, despite the presumably xeric conditions downwind from the PIS margin. Comparison with high-latitude paleoclimate records suggests that southward shifts/contractions of the westerlies toward or beyond Tierra del Fuego enhanced upwelling and ventilation of deep waters in the Southern Ocean. Northward shifts/expansions had the opposite effect, similar to the zonally symmetric weakening of the westerlies during the early Holocene. We observe that the time evolution of atmospheric CO_2 concentrations, high-latitude air and sea-surface temperatures, and sea level during T1 fall short in explaining the timing and abruptness of the Bahía Inútil glacier lobe collapse, and quite possibly multiple other glacier lobes from the PIS.

Paleoclimate and paleoceanographical interpretations using bioerosion ichnodiversity patterns in the southern South-Western Atlantic at Patagonia, Argentina

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Marine Late Quaternary skeletal concentrations from Argentina are rich in mollusks, extending more than 3,000 km between the Río de La Plata and southern Patagonia, where those formed during MIS11, 9, 7, 5 and 1 are the best preserved along the SWA. In this work we will analyze Late Pleistocene, Holocene and modern Patagonian deposits, where detailed field and laboratory observations carried out on bulk samples, allowed to identify a great variety of bivalve and gastropod taxa which testify an interesting history of paleoclimate-paleoceanographical-changes to present. In the molluskan fauna a great variety of bioerosion traces were identified (up to 15 ichnogenera) made by porifers, bryozoans, annelids, other gastropods and brachiopods. In general, the most characteristic traces are those produced by bryozoans, polychaetes and predatory gastropods. No strict correlation is evident between ichnodiversity patterns through time or latitude, but it is possible to observe a linkage to local oceanographical/biotic controls. In modern samples, most of the ichnotaxa were made by bryozoans, showing a general trend of higher bioerosion degree and ichnodiversity at higher latitudes. This pattern is controlled by sea surface temperature and productivity, as several ichnodiversity peaks for modern localities match with well constrained conditions (substrate, salinity, coastal fronts). Similarly, this applies for the Holocene. By contrast, not for the Late Pleistocene, when dissimilar conditions probably prevailed, especially during the Last Interglacial (colder waters richer in nutrients) as a response to different paleocirculation settings (winds, currents, ocean fronts). An exception to this general pattern is observed at San Matías Gulf (northern Patagonia), where local paleo-oceanographical conditions control the water-productivity levels affecting the bioerosional patterns (i.e. upwelling currents related to the gulf opening). In conclusion, the macrogeographical distribution of trace fossils, at least for Patagonia, could be used for interpreting the strong linkage between Earth history-climatic cycles-atmospheric-oceanic circulation patterns and Late Quaternary biotic responses, illustrating future potential climate change consequences for nearshore communities.

Session 155: Linking land and sea - multiple approaches to investigating human-environment interactions in the coastal zone

Buried landscapes offshore Belgium: investigating the drowned Testerep peninsula

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The Belgian coastal plain is a unique landscape shaped by the interaction of natural processes and human activities. It was once a dynamic tidal environment of channels, sandflats, dunes and salt marshes, now transformed into a densely populated and developed region threatened by relative sea-level rise, which also posed a risk to the coastal plain and its society through time. The interaction between geomorphology, past environmental conditions and the strategies developed by the people living in this landscape have shaped the large-scale coastal dynamics that have led to the present-day situation. This past evolution can offer valuable lessons for future actions to create a more sustainable coastline. This is the aim of TESTEREP, an interdisciplinary research project focusing on the evolution of the Belgian Middle Coast during the past 5000 years.

A large peninsula known as Testerep was once located on the Belgian coastal plain between the cities of Nieuwpoort and Ostend. The gradual degradation of the seaward side of the peninsula culminated in the historically and archaeologically attested abandonment of settlements in the 14th century, whilst the landward part has been heavily reclaimed. The offshore extent of the former peninsula has now been investigated by the combined analysis of high-resolution seismic profiles, magnetics, and sediment cores, revealing complex palaeolandscapes buried beneath the seabed. Large-scale channel belts are preserved to the east and the west of the former peninsula, pointing to the location of palaeo-valleys which migrated as the sea level rose. These channels are linked to a tidal environment preserved between the present-day coastline and a tidal sandbank. Here, acoustic anomalies recognised in the seismic records allowed the identification of several peat deposits cut by small tidal creeks, which represent former land surfaces subsequently drowned by the sea. Broad prograding bodies, corresponding to old coastal barriers, are found parallel to the coastline overlying a sub-horizontal transgressive surface. The reconstruction of the evolutionary phases of these paleo-landscapes will be used as the base for the morphodynamic modelling of the coastal evolution and the investigation of the erosional and depositional patterns that drove the coastline retreat.

Sedimentary multi-proxy records of human-induced environmental changes in the estuarine lake Nakaumi, southwest Japan

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The coastal zone is a naturally vulnerable system and is subject to significant human-induced impacts such as eutrophication and pollution. We investigated the multiproxy records for 600 years in the sediment from Lake Nakaumi, an estuarine lake in Japan, to place the consequences of multiple stressors on coastal ecosystems into a larger temporal context.

We established the stratigraphy of bottom sediments at site Nk-3C in Lake Nakaumi based on the lithofacies, soft X-ray photography and CNS elemental analysis of three sediment cores. Using the age model inferred from ^{137}Cs, ^{210}Pb and ^{14}C dating, the core sediment is estimated to be deposited for the past 600 years, and the sedimentation rates ranges between 0.24 and 0.38 cm/yr.

From the 1400s to the mid-1900s, ostracode assemblages indicate the transition into more oxygenic environment in the bottom of Nakaumi. In this period, CNS elements indicate decreasing trends due to the dilution effect of increased clastic supply. This suggests the change of the mouth position of inflow rivers and the increase in water flow. Although the direct relationship could not be specified, the dominant horizons of a foraminiferal species, *Ammonia beccarii*, which coincides with the development of lamination in the corresponding stratigraphic level and the decrease in TOC and CN, are recognized three times during this period. After 1800 CE, the development of copper and molybdenum mines in the catchment areas are detected as a sharp increase in Cu and Mo concentration around 1900 CE. In the 1960s, CNS and many kinds of heavy metals show a rapid increase, the total abundance and ostracode diversity decreased, and eutrophic species of foraminiferas and diatoms increased. This rapid change indicates that the drastic shift in the aquatic environment was caused by loads of industrial and domestic wastes and the intense stagnation due to the construction of the port area. Multiproxy records which revert to the past value in the 1960s suggest the environmental recovery in Nakaumi. This reverting trend occurred much earlier than that of the metropolitan bay area such as Tokyo Bay and Osaka Bay in which the environmental degradation progressed more after the 1960s.

Sedimentary Records of Trace Metal Pollution in the Erdek and Bandırma Bays, Marmara Sea, Türkiye: History and Contamination Degree

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The Erdek and Bandırma Bays in the southwestern part of the Marmara Sea have been adversely affected by increasing population, discharge of urban and industrial wastewater, densely used chemical pesticides and fertilizer heavily used in agriculture as well as domestic wastes and port activities. Sedimentological and geochemical analyzes of four core samples taken from Erdek and Bandırma Bays were investigated to evaluate the trace metal (As, Cr, Cu, Hg, Ni, Pb, V and Zn) pollution status, historical trends and contamination degree during the sediment deposition.

The core sediments consist mainly of clay (9-96%), silt (1–78%) and sand (0.1-20) with small amounts of gravel (0.1–7%). The range of As, Co, Cr, Cu, Hg, Ni, Pb, V and Zn concentrations in mg/kg in all core sediment samples are 0.5-28 (As), 0.1-21 (Co), 31-395 (Cr), 0.1-58 (Cu), 0.03-1.10 (Hg), 11-196 (Ni), 3-72 (Pb), 19-159 (V) and 6-255 (Zn). The results of CF and PLI reveal that the upper 20 cm core sediments in Erdek Bay were contaminated with Hg, Pb and Zn by both anthropogenic and lithogenic input via the Biga and Gönen streams. Furthermore, the upper 20 cm of MD72 and BK1 core sediments taken from Bandırma Bay were moderately polluted with As, Cu, Hg, Pb and Zn caused by the discharge of untreated industrial wastewater and domestic sewage from the surrounding area of Bandırma Bay. Moreover, lithogenic Pb-Zn was transported to Erdek Bay by Biga and Gönen streams from the Pb-Zn mineralized zones in the southern Sea of Marmara drainage area. C-14 dating reveals that As, Hg, Pb and Zn contamination in the study area was started about 400–500 years before the present based on preliminary sedimentation rate estimates and has increased intensely in the last century. The present study was supported by Research Fund of Istanbul University, project number FBA-2021-38098

Baseline assessment of metal contaminants at inshore reef settings

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As the Great Barrier Reef (GBR, Queensland, Australia) becomes increasingly threatened by unprecedented marine heat waves, it also remains at risk from ongoing coastal development. Yet despite current policy and management augmenting efforts to improve water quality by monitoring levels of sediment, nutrients and pesticides, there remains limited (available) baseline data on the presence of metals and metalloids in coastal waters, despite evidence for their toxic effects at elevated levels on a range of marine organisms. We present preliminary results of ongoing investigation on trace metal and metalloid concentrations in modern surface intertidal sediments as well as historical sedimentary deposits from cores collected from one of seven sites surveyed around popular inshore reef locations along the GBR.

Concentrations of As, Sb, Sn, Cd and Hg in twenty surface sediment samples from Edgecumbe Bay were found to be consistently 3-20 times enriched than average alluvial sedimentary values for Queensland. For two samples, levels of Cu exceeded commonly applied sediment quality guidelines, while Cr, Ni, Zn and Pb were above the range of concentrations defined for Queensland sediments in five samples, suggesting potential negative effects on biota. Modern concentrations were also found to be higher compared to historical deposits, chronologically constrained using uranium-thorium dating of adjacent coral material.

These results, although preliminary, provide a baseline understanding of these contaminants of emerging concern. Comparison with the other sites will provide an assessment of their ecological risk to local biota and will help ongoing monitoring of pollutants along the GBR for future conservation plans. This is especially important in view of increasing sediment input to the reef caused by abrupt weather events (cyclones, floods, storms) due to climate change.

Anthropogenic signatures and reference conditions in marine sediments from Italian coastal areas affected by different types of impact

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Marine sediments are extraordinary archives of past events because they preserve many proxies of environmental changes, and sediment cores are suitable tools for reconstructing (paleo)environmental patterns. This work considered three marine sediment cores from earlier studies, collected at shallow water depths in front of sites that have been home to different types of past anthropogenic activities, causing different types and extent of contamination of marine sediments, and active in different historical periods. Grain size, metals, trace elements, and organic contaminants have been analyzed, and benthic foraminifera have been studied to be applied as environmental indicators. Moreover, a geochronological characterization was carried out based on different methods such as luminescence dating, ^{14}C, ^{210}Pb, and ^{137}Cs.

This work aimed to deduce general information on the characteristics of the anthropogenic signatures in marine sediments of Italian nearshore areas.

The different anthropogenic activities produced complex contamination in the three cores due to different parameters, whose high-resolution profiles were reconstructed along the depth. The geochronological characterization, integrated with historical information, allowed the attribution of significant changes in concentration patterns to well-known events. In addition, benthic foraminifera showed different responses to contamination, such as changes in assemblage composition, an increase of tolerant species, and a decrease in absolute abundance, which may be used as proxies of the ecological status.

From these case studies, it was deduced that: a) relatively high sedimentation rates of coastal marine areas allow to reconstruct of environmental changes at a decennial scale; b) the geochronological study needs to be integrated with historical information to attribute the changes of contaminant profiles to specific events; c) the first record of synthetic contaminants may be used as a chronological marker; d) the recovery of old uncontaminated levels provides reference conditions; e) each type of anthropogenic activity produces a mix of contaminants with different effects on benthic foraminifera that can be quantified and used as proxies for the (paleo)ecological status.

Foraminiferal Ba/Ca as coastal recorder of drought

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Unprecedented drought and heatwaves have been increasing in recent years under global climate change. To assess drought periods in paleoclimate archives pre- and post-anthropogenic warming, reliable proxies are essential. In coastal regions, seawater barium (Ba) concentrations are directed by hydroclimatic conditions via riverine input of terrestrial-derived Ba, and can be inferred from biogenic calcite (Ba/Ca). Benthic foraminifera are abundant in coastal sediments and generally considered reliable geochemical proxies for high-resolution archives at the land-sea transition zone. However, the use of benthic foraminiferal Ba/Ca as indicator for terrestrial discharge specifically is rare and has never been validated. Here we explore the impact of the severe drought and heatwave over northern Europe in 2018, followed by a warm and wet year, on Ba/Ca of living (CTG-labelled) benthic foraminifera (*Bulimina marginata, Nonionellina labradorica*) from a Swedish sill fjord (Gullmar Fjord, northern Europe). Benthic Ba/Ca, derived from laser-ablation ICP MS, significantly correlates with riverine runoff during 2018–2019. In consultation with solid and dissolved trace elemental profiles we deduce that shallow-dwelling species are especially reliable as discharge proxy and propose potential mechanisms of Ba shuttling in the fjord's water column and sediment. While the drought-induced disruption of terrestrial Ba supply caused anomalously low benthic Ba/Ca signals, additional but minor Ba/Ca variability was introduced by distance to Ba-source, input of low-Ba seawater and species-specific vital effects. If these factors are considered, benthic foraminiferal Ba/Ca from near-coast environments has potential as a reliable proxy for continental hydroclimatic conditions, opening new opportunities to track drought histories throughout geological timescales.

A stormy past: a high-resolution Holocene storm reconstruction from a coastal bog, north-western Ireland

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Substantial uncertainties exist regarding how future climate change will affect storminess (a term that includes both frequency and intensity) in the eastern North Atlantic. Knowledge about spatiotemporal variations of past storminess can contribute to a better understanding of the mechanisms that govern storminess on centennial to millennial time-scales, which can shed light on the potential impact of external forcing on future storminess in climate models. Here, we present a unique storm record, covering the last 10 000 years, reconstructed from a coastal bog, in north-western Ireland. The sequence was analysed for grain size (Mastersizer 3000), chemical (EMMA-XRF), mineral (pXRD) and molecular composition (FTIR-ATR). The chronology is built on 11 AMS radiocarbon dates. The low inorganic content throughout the studied period, together with the grain size sorting, indicate that the minerals were mainly transported via aeolian pathways to the bog. The grain size analysis, conducted at decadal resolution, allowed differentiating between (fine) long-distance travelled dust, and coarser short-distance travelled sand particles. While the fine particles likely represent changes over a larger spatial area (e.g., changes in vegetation cover, dryness), the sand content likely represents regionally changing sea levels, dune building and periods of increased storminess. Increased storminess, inferred from the ratio between silt and sand sized particles, was recorded (cal BP) for the periods 6700–5500; 5070–4180; 3500; 3250; 2830–2480; 1940–1830; 1440–1100; 970; 510 and 290. The early Holocene was characterized by lower mineral input, finer grain sizes, and gradually drier conditions. Most of the storm episodes until 2000 cal. BP coincide with cold periods and wetter conditions, suggesting that an increasing thermal gradient between mid- and high latitudes, together with shifts in the sea-ice front affect the westerlies over the eastern North Atlantic. The de-coupling between regional climate and our record during the last 2000 years could be related to latitudinal shifts of the storm track, increasing human activity in the study area, local changes in source supply, or dating uncertainties. To resolve these uncertainties, additional paleostorm studies are required (e.g., north and south of our study location) together with paleoecological investigations (pollen, plant macrofossils).

The circulation of obsidian in the Strait of Sicily during the Holocene: A view from the Eastern Maghreb

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The research presented here is part of a wider project carried out in the Eastern Maghreb which is aimed at detecting socio-cultural and economic changes among Epipalaeolithic Capsian and Neolithic groups in Northern Tunisia. The transition between the Early and Mid-Holocene in this region witnessed the gradual adoption of features that are usually associated with a Neolithic economy - within a hunting-gathering style of life: the presence of pottery, the introduction of domestic animal species, the appearance of pressure technique, and use of obsidian.

In particular, the discovery of obsidian artefacts in several archaeological sites of Central and Northern Tunisia, where sources of this material are not present, suggests that the Capsian and Neolithic groups of the Eastern Maghreb were undertaking seafaring activities across the Central Mediterranean, especially within the Strait of Sicily.

The five obsidian artefacts presented in this paper come from the Capsian sites of Sidi Aïch, in the Gafsa region, Khanguet Feriana, Khanguet N'am, and Oued Bou Haya, all in the Kasserine region, and from the Neolithic cave of Djebba, in the Beja Governorate. These artefacts were analysed through non-destructive and micro-destructive methods of elemental characterization: XRF, XRD, and LA-ICP-MS. The results were compared with those obtained from the analysis of geologic sources from Pantelleria and Lipari.

The application of these techniques reveals the Southern Italy provenance of the obsidian exploited for manufacturing the artefacts found in the Tunisian sites, and thus confirms that the human groups of the Eastern Maghreb were included in exchange networks across the Strait of Sicily.

Session 156: Multidisciplinary approaches of calcareous tufas and travertines: investigating environments and climates from Prehistory to today

Why is tufa not depositing anymore at lowland alkaline fen in Central Europe? Insights from monitoring and paleoecological data

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Tufa depositing alkaline fens, formerly abundant, have been decreasing in numbers since the mid-Holocene, first due to natural causes and recently due to human impact. Actions undertaken to protect and restore those ecosystems include restoring conditions favouring tufa deposition, which assures a proper substrate and allows for retention of low fertility of the fen by nutrient bonding during $CaCO_3$ precipitation. In the present study, we aim to: i) reveal the limiting factors for tufa accumulation at the alkaline fen in Turtul, Suwalski Landscape Park, NE Poland, holding the history of heavy $CaCO_3$ precipitation during the early and mid-Holocene; ii) evaluate the potential for reestablishing carbonate deposition. To complete our aim, we investigated the current fen ecosystem, which included botanical and malacological inventory and yearly monitoring of the physicochemical properties of the groundwater emerging at the fen and testing whether $CaCO_3$ precipitates there. Also, we studied the long-term responses of biotic and abiotic components of the fen ecosystem to environmental changes since the tufa deposition declined ca. 5400 cal yr BP. The decreased temperatures at the fen surface resulting from climate cooling and the entering of trees at the fen were likely responsible for the ceasing of tufa deposition in the mid-Holocene. At present, despite the unfavourable conditions for $CaCO_3$ precipitation, i.e., negative or neutral calcite saturation index, calcite crystals were observed in the spring and summer. Precipitation of calcite indicates the importance of the autotrophs, which absorb CO_2, locally increase pH and provide sites for $CaCO_3$ nucleation. The combined effect of global warming and cutting down the birch stands are likely to increase the temperatures at the fen surface, reactivate tufa deposition, and help restore the proper alkaline fen ecosystem. Currently, the calcium-rich substrate is indicated exclusively by *Carex paniculata* and two gastropod species, *Vertigo geyeri* and *Vertigo angustior*.

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CO2 storage in tufa: non-traditional isotopes as quantitative identifiers of authigenic carbonate

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The authigenic carbonate is a potent, but highly dispersed CO_2 sink, which has not been adequately quantified yet. Karstic tufa-precipitating streams are ideal settings for studying the magnitude of geological CO_2 fluxes because they encompass a traceable nexus of carbonate weathering, transport of particulate and dissolved inorganic carbon (DIC), CO_2 degassing and precipitation of secondary (authigenic) carbonate. The tufa represents a mixture of authigenic and detrital carbonate and non-carbonate bedrock weathering products contributed by surface run-off or atmospheric input; but carbonate in tufa can originate from different sources, too. To evaluate the potential of tufa as a CO_2 sink, the authigenic carbonate needs to be discriminated from detrital or soil carbonate and quantified separately. Although C and O isotope compositions in principle reflect the origin of carbonate, the quantification of carbonate sources is not always possible based solely on the C and O isotope compositions, in particular in lacustrine sediments. Recent investigations showed that the isotope fingerprints of tufa reflect the complexity of the local hydrology and that in such complex settings, U and Sr isotopes are better identifiers of authigenic carbonate than C and O isotopes. The quantification of authigenic carbonate, however, requires extensive characterization of local sources of detrital carbonate and dissolved load in the river and interstitial water.

We report on the use of U and Sr isotope fingerprints of bedrock, soil, tufa and dissolved metals for quantification of the authigenic carbonate in recent tufa formed at main barriers and in lakes at the Krka River (Croatia). The annual CO_2 storage in barrier tufa was calculated from carbonate precipitation rates (obtained using the Diffusion Boundary Layer model) and the estimated fraction of authigenic carbonate. In the studied system, it exceeded the annual CO_2 storage of temperate forests. In lentic environments, the sedimentation rate is the critical parameter for the determination of carbonate deposition, however, the net C fluxes to or from the sediment depend on the trophic status of the lake and the ratio of carbonate sedimentation rate and carbonate dissolution rate in the recent sediment.

Potential of MIS 5 and MIS 1 fluvial tufa deposits as palaeobotanical archives: examples from the Iberian Range (Spain)

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The Iberian Range harbors tufa deposits associated with the current and past drainage network. These continental carbonates represent the external sedimentary response to the dynamics of karst systems and, therefore, constitute excellent palaeoenvironmental archives. Indeed, the well-preserved palaeobotanical proxies in the multiple fluvial tufa deposits along the range (e.g., Trabaque, Matarraña, Queiles, Val and Martín rivers) allow us to reconstruct both local and regional vegetation response to Upper Pleistocene and Holocene climate and hydrological variability. During MIS 5, chronologically placed between 130030 and 120610 yr BP, the vegetation in the southern Iberian Range was defined by Mediterranean pines (e.g., *Pinus pinaster* type), xero-thermophilous trees and shrubs (e.g., *Quercus ilex/coccifera* type, *Juniperus*, *Olea europaea*, *Cistus ladanifer* and Lamiaceae) and mesophilous trees, (e.g., *Alnus*, *Betula*, *Celtis australis*, *Corylus avellana*, *Fraxinus* and *Quercus faginea/pyrenaica* type) denoting a slightly milder and wetter climate than the present, while colder but still humid conditions are reconstructed for the 117000 ± 3500 yr BP and 103000 ± 4700 yr BP interval according to pollen and leaf imprints analysis (e.g., *Pinus nigra, Salix purpurea, S. eleagnos, Populus alba, Alnus glutinosa, Corylus avellana, Quercus faginea, Sorbus aria, Acer opalus, Fraxinus excelsior, F. angustifolia, Buxus sempervirens*, *Pistacia terebinthus*). During the Greenlandian (MIS 1, 9540-8380 cal yr BP) montane pine communities (*Pinus sylvestris/nigra* type), junipers and xerophilous taxa (e.g., Poaceae, *Artemisia*, Fabaceae, *Genista* type, *Helianthemum*) were the main landscape elements, while the riparian forests (e.g., *Corylus avellana, Castanea sativa, Juglans regia, Ulmus, Fraxinus, Salix, Populus*) and the Mediterranean woodland (e.g., *Quercus faginea/pyrenaica* type, *Quercus ilex/coccifera* type, *Pistacia, Rhamnus, Phillyrea*) acquired maximum representation during the Nordgrippian (MIS 1, 7590-5820 cal yr BP). The return of montane pinewoods synchronous to the depletion of mesophilous trees and the decline of tufa growing characterize the transition towards the Meghalayan (MIS1, ca. 4995-4060 cal yr BP) as consequence of increasing arid conditions at Iberian-scale.

Subannual-to-biannual-resolved travertine record of Asian Summer Monsoon dynamics in the early Holocene at the eastern margin of Tibetan Plateau

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The response of decadal to centennial variations of Asian Summer Monsoon (ASM) intensity in the early Holocene to solar activities and/or earth internal forces remains a major question in quaternary research. In this study, we present a subannual–biannual-resolved (0.9–2 years) ASM intensity record spanning from 11.6 to 10.0 ka BP (before 1950 AD) inferred from a ^{230}Th-dated travertine δ^{18}O record at Zhangjia Ravine on the eastern margin of the Tibetan Plateau. The ASM intensity dynamics are consistent with North Atlantic climate changes recorded in Greenland ice cores and Cariaco Basin marine sediments in the early Holocene. This observation confirms the teleconnection between the ASM and North Atlantic climate. Our inferred ASM intensity variations are generally consistent with changes in sunspot number, implying a potentially instant response of ASM to solar activity at decadal-to-centennial timescales. There are several abrupt changes in the δ^{18}O sequence, which indicate that the ASM in the early Holocene was highly unstable. Comparison with marine records suggests that the Preboreal oscillation (PBO) event could be triggered by a freshwater outburst which the sudden release of thousands of cubic kilometers of the meltwater to the North Atlantic Ocean. Furthermore, the climate oscillations during the PBO were associated with the complex interplay of solar activity and freshwater outburst, the freshwater outburst may amplify the effect of solar activity when it was in the minima. The rapid warming after the PBO event may be controlled by the common mechanism that induced the Dansgaard–Oeschger warming events during the last glacial period. This study is not only important to understand the primary driving force of the ASM intensity in the early Holocene, but also essential for evaluate the probability of abrupt climate changes in the future.

Fall and rebirth of Holocene tufa in Slovak Karst (Western Carpathians) - a possible human influence

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Several tufa complexes are known in the Slovak Karst. It is a typical karst area of a temperate climate built of Mesozoic carbonates, mainly Triassic in age. Carbonate plateaus are drained by karst systems which lead water to resurgences located in the valleys up to 300 m deep. Below the resurgences there are Holocene fossil tufa that exceeds 12 m in thickness. Two depositional systems were recognized within the tufas studied: (i) a perched springline transverse system, and (ii) a longitudinal fluvial depositional system.

The studied tufas flourished in the Mid-Holocene, namely in the Atlantic and Sub-Boreal times. Subsequently, they experienced substantial erosion and were incised, locally even down to their Mesozoic basement. Erosion was preceded by the instability of valley slopes, which resulted in the deposition of colluvium in the uppermost part and on the top of the tufa complexes. The instability was most probably caused by deforestation of karst plateau slopes. One can hypothesize that deforestation impacted the tufa depositional system in at least a twofold way: (i) via increase in the erosive capacity of streams, and (ii) via decrease in the dissolved calcium carbonate content of the stream water. It seems plausible that the forest retreat in Slovak Karst reflected growing pastoral or agricultural activity of prehistoric humans. Coincidence with establishment of the Kyjatice or Hallstatt culture in the area studied supports this view. Artefacts from these cultures have been found not only in tufas but also in numerous caves, including those near the tufa sites. The above scenario supports the theory that prehistoric humans influenced the cessation of tufa growth since they were responsible for deforestation, which in turn created conditions triggering the disintegration of tufa.

Whatever the factors that stimulated disintegration of tufa and incision of streams, they ceased to operate, as modern tufa is extensively growing at all the studied sites. Neither the precise time of the switch from disintegration to the growth of tufa nor the factors controlling it are known. One possible explanation is a partial regeneration of forests caused by low regulations in the mid 18th century in the Austrian monarchy.

Events recorded in travertine sequences in central Italy during the last glacial period

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U-Th dating has shown that about 44 ka ago the accumulation rate of the main travertine plateaus of central Italy, Tivoli and Canino, about 100 km apart from each other, recorded a sharp decline. At Tivoli this event was also marked by an interruption in carbonate accumulation for at least 3-4,000 years. At Canino, an isotopic chronostratigraphy carried out on a travertine sequence that identifies the period 55 – 10 ka, confirmed the evidence that emerged through the dating of the Tivoli deposit; the isotopic curves have in fact identified a shift between 47 and 43 ka which correlates well with the decrease in the accumulation rate. Probably, this dramatic event has paleoclimatic causes which contributed to modulating the water tables in the respective hydrological systems and therefore the travertine depositional-erosional process. However, since Tivoli and Canino are endogenous travertines, both involved in the late Pleistocene tectonic activity, a tectonic control, that conditioned the rise of crustal fluids rich in CO2, could have played a crucial role.

The interplay of these two factors is difficult to evaluate in these contexts. A recent study on a drilling carried out on the right bank of the Tiber River valley, immediately north-east of Rome, has provided a significant contribution to clarifying this aspect. The core drilling showed the presence of a 3 m thick travertine body, lying below 8 m of recent alluvial deposits. It was studied for isotope and chemical stratigraphy, and U-Th dating. This travertine is associated with the rise of hypothermal, saline water and a deeply derived CO2 gas emission.

The chronostratigraphic investigation has shown that this travertine body was formed in the period 55-20 ka, and, despite the vastly inferior dimensional scale to the plateaus of Tivoli and Canino, it showed similar features, in particular the 44,000-year event in which the sharp decrease in the accumulation rate occurred. Chemo and isotope stratigraphy has described a temporal evolution of events in which climatic variations are superimposed on tectonic effects and has revealed that paleoclimate likely played a key role in triggering tectonic activity.

8.2 and 7.4 ka BP climatic events and human occupation recorded in travertine at Santovka (Slovakia)

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The interrelation of climate change and human society in prehistory presents a multidisciplinary scientific problem, which could be revealed by research on fresh-water carbonate sediments. Such palaeoclimatic and archaeological archives were unearthed at the Santovka site (Slovakia), where travertine lake sediments of the Mid-Holocene age were discovered. Our intent was to directly compare evidence of human activity on the transition from the Mesolithic to Neolithic period with that provided by palaeoclimatic and palaeoenvironmental records. To achieve this, we intended to employ proven methods of geoarchaeology, isotopic geochemistry and palaeoecology, and our innovative applications of markers of human faeces. A considerable anthropic impact was represented by increased lipid coprostanol and charcoals during the second half of the 8.2 ka BP global climatic event. Abrupt drying of the lake environment at about 7.4 ka BP was contemporary with increased human activities associated with the Linearbank Keramik culture at the site.

New palaeoenvironmental investigations deduced from molluscan assemblages of a Middle Atlas tufa (Morocco)

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Calcareous tufas provide a reliable sedimentary environment and favourable preservation conditions for the study of fossil land-snails assemblages. They represent a relevant bio-indicator and are complementary to other biological proxies (e.g. pollen, ostracods…) to describe the variability of the evolution of Mediterranean environments. However, the use of Holocene malacological assemblages is an approach that is gradually emerging in Morocco. Except for studies on continental molluscs linked to archaeological matters, continuous malacological sequences remain seldom conducted. In northeastern Morocco, several recent studies enable the construction of a first reference frame of palaeoenvironmental variations deduced from non-marine mollusc.
The Aït Said ou Idder tufa located in the Middle Atlas comprises a stratigraphic sequence that records part of the Late Pleistocene and the Middle Holocene. The multidisciplinary study of 3 outcrops of this deposit includes malacological and geochemical (oxygen and carbon stable isotopes) investigations. The evolution of malacological assemblages suggests first elements of the environmental context during D/O 8and MIS 5e. The Holocene succession presents a rich fauna of palustrine and hygrophilous taxa typical of wetlands and analogous to other malacological sequences of the Middle Holocene. In the upper part, more xero-resistant taxa develop and imply the first evidence of aridification during the second half of the Middle Holocene. The new malacological data obtained for the Aït Said ou Idder tufa are consistent with geochemical analysis obtained at the site and with regional palaeoenvironmental records.

Session 157: Peatlands through time: developmental dynamics and palaeo-environmental reconstruction

Spatiotemporal dynamics of peat initiation across the central Congo Basin

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The central Congo Basin contains the world's most extensive tropical peatland complex, which acts as a significant component in the global carbon cycle. Until now, limited radiocarbon dating indicated that peat formation began at least ~19,250 calibrated years Before Present (cal yrs BP). We analyse 31 radiocarbon dates from basal peat samples that provide new insights into the spread of peat across the basin. Our samples represent both interfluvial basin peatlands that are more common in the west of the region, and river-influenced peatlands that are more prevalent in the east. Here we show that peat first initiated in the central Congo Basin much earlier than previously believed. The oldest dates are from river-influenced peatlands on the floodplains of left-bank tributaries of the Congo River, indicating a high degree of channel stability in these rivers. Peat has been a persistent feature of the central Congo Basin for tens of millennia, but recent evidence of peat loss during past periods of severe drying raises questions about the stability of this globally-important carbon store in the face of future climate change and direct anthropogenic alteration.

Holocene environmental changes inferred from a Mauritia peatland palm swamp (aguajal) and an oxbow lake cores in the Madre de Dios region, southeastern Peru

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Mauritia flexuosa dominated palm swamps (called *aguajales*) are typical peatlands in Madre de Dios River floodplains in southeastern Peru. To understand *aguajales* in that region, we investigated the late Holocene records of the local and regional vegetation dynamics, peatland evolution, organic carbon (C) accumulation, paleoclimate, and human impact using cores collected from the Los Amigos *Aguajal* (LAA) and oxbow lake (LAL) located within LAA.

LAA results show that the sedimentation started within shallow water, ponded on an impervious substrate within an abandoned river channel (1380–820 cal yr BP) located adjacent to a steep escarpment with *terra firme* (upland) rainforest and lateral to floodplain forests. This was followed by the development of a marshland (820–640 cal yr BP). A closed canopy *aguajal* established itself (640–300 cal yr BP) which later changed into an open canopy *aguajal* mixed with *Hedyosmum* (300 cal yr BP to present). Two major changes in peat and C accumulation rates were observed: An onset at 820 and a decrease after 520 cal yr BP. The peat and C accumulation rates in LAA were faster ca. 4 mm yr^{-1} and ca. 200 g m^{-2} yr^{-1} respectively, or similar to some *aguajales* in northern Peru.

LAL record, spanning the last 4260 cal yr BP, shows that the oxbow lake belonged to a meander of the Madre de Dios River, and was cut off at 1760 cal yr BP. The climate remained wet in 1760–640, but subsequently became less wet until the present except for the period of 610–540 cal yr BP. The charcoal results show that there was almost no human activity in the study area since 4260 cal yr BP. Comparison of LAL and LAA shows (1) the similarities and differences of vegetation dynamics on local and regional scales; (2) the main environmental changes in LAA may correspond to local moisture changes. LAL results show the opposite paleoclimate changes compared to the Peruvian Andes which might be related to elevation differences and/or non-climate disturbances influencing the existing records.

Mid- to Late Holocene vegetation changes and climate variability on the North Atlantic from Caveiro Lake margin peat record (Pico island, 38ºN, Azores archipelago)

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A multiproxy study was applied to a 9m long record recovered from the peatland located at the NW margin of Caveiro Lake (Pico Island, Azores archipelago). Results of peat stratigraphy, elemental and stable isotope geochemistry on bulk organic matter and macrofossil analysis were used to infer past water levels and vegetation changes. From 6700 to 4300 cal yr BP, the sequence consists in a sedge peat with intercalations of tephra layers. During this period, high runoff events are recorded as layers with high mineral and transported woody remains, depicting high Total Organic Carbon (TOC>30%). From 4300 to 2750 cal yr BP the island undergoes a humid period that results in an important rise in water table. This is recorded by the accumulation of dark organic mud facies with low TOC/N ratios and abundant aquatic fauna. From 2750 cal yr BP, the Caveiro record depicts a terrestrialization characterized by the alternation of a dry phase dominated by a laurisilva shrub tree vegetation and a wetter phase consisting in a sedge-fen community that indicates a low water level, close to the surface. Dry shrub assemblage is interpreted from a peat rich in *Juniperus*, *Calluna*, moss and fern remains and high ∂^{13}C values (-26‰). Sedge-fen phases, instead, are recorded by the accumulation of peat made of Cyperaceae (chiefly *Carex*) and *Juncus* remains and lower ∂^{13}C values (-29‰). Lacustrine deposits associated with high water level are recorded as short events at 2530, 2060 and 1700 cal yr BP. The uppermost part of the sequence, from 1650 AD to the present, consists in Sphagnum peat. This finding is consistent with several records across Azores Archipelago: vegetation communities surrounding the lakes disappeared by human induced land use changes leading to *Sphagnum* dominated environments. Littoral communities are very sensitive to water level changes and therefore very adequate for reconstructing autogenic, environmental and precipitation changes. Because precipitation in Azores is mainly triggered by non-stationary interactions among North Atlantic Oscillation (NAO) and other climatic modes, this record contributes to a better knowledge of the role of long-term NAO changes and large-scale climate patterns of variability for the Holocene.

Late Holocene hydroclimatic changes across southern Patagonia reconstructed by peat bogs

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The southern westerly winds influence weather patterns and water resources across the southern high-latitude regions, with important socio-economic impacts. The strengthening and poleward migration of these winds since the late 20th century also have implications for regional environmental change, including drought, wildfire, and sea-ice loss. However, it is challenging to recognize the natural variability of the westerlies and predict their future behavior, as those recent changes have been influenced by anthropogenic factors. Here we present a 4200-year-long record from a southern Patagonian peatland in a location that is sensitive to changes in the position/strength of the westerlies. Our $\delta^{13}C$ record shows a 6‰ increasing trend from 4200 to 1200 cal. BP, indicating a progressive, millennial-scale increase in peatland moisture. This long-term trend is attributed to an increase in moisture induced by strengthening SWW associated with a change in the mean state of the El Niño–Southern Oscillation (ENSO) system. Superimposed on this millennial trend are centennial-scale shifts in hydroclimate that persist into modern times. We suggest that a “paleo” Southern Annular Mode—that is linked to tropical Pacific climate, with dry events contemporaneous with positive phases and La Niña-like conditions—is responsible for this enhanced hydroclimate variability. Overall, our results point to millennial- and centennial-scale changes in hydroclimate during the Late Holocene that link tropical Pacific climate variability with the Southern Annular Mode and the southern westerlies, with far-reaching implications for future changes in the southern high latitudes, including CO_2 ventilation from the Southern Ocean.

Holocene dynamics of wildfires, vegetation change and carbon accumulation in Falkland Islands' peatlands

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Large areas of the Falkland Islands/Malvinas are covered by peatlands. Their position in the South Atlantic puts them under strong influence of the southern westerly wind belt on the leeside of the Andes, resulting in relatively low annual precipitation and severe evapotranspiration. In one way or another, these factors also control naturally occurring wildfires. In addition to erosion, caused by the introduction of livestock a few centuries ago, a projected change towards higher wind intensity and less precipitation is another threat for the future of the Falklands' vulnerable peatlands and their ability to maintain the vegetation cover, to retain and store water, and to eventually accumulate peat and carbon.

To better understand these dynamics, cores from white grass (*Cortaderia pilosa*) and *Sphagnum* dominated peatlands are analysed. The main set of tools consists of looking in detail at past changes in the macrofossil record, the occurrence of macro-charcoal particles and the amount of carbon stored over different time periods. Identifying transitions from wet to dry-indicating vegetation and vice versa can give insight into former periods of climate change, and to potentially tie them to changes in the intensity and position of the westerlies. However, the mechanism behind layers with episodically high amounts of charcoal found in our records (i.e. a high frequency of wildfires), is not simple. Did wildfires spread because of drier conditions? Were they fanned by stronger winds? Or did wetter conditions favour the growth of more combustible material (vegetation)? One of the ways to tackle these questions is using Raman-spectroscopy on charred plant remains to gain information about the intensity of palaeo-wildfires.

Combining this approach with our collection of macrofossil data gives first insights into the Holocene evolution of selected sites on the Falkland Islands and the effects of regional climate changes.

Repeated forested peatland fires in sporadic permafrost zone in Western Canada

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Wildfires have a crucial role in northern boreal peatland ecosystems as drivers of ecosystem functioning affecting vegetation composition and biomass, peat accumulation patterns and soil carbon (C) stocks. Especially, the northern permafrost peatland ecosystems are under pressure due to the climate warming and increasing anthropogenic impact. The frequency and severity of wildfires is predicted to increase in the future, and therefore knowledge of long-term natural fire dynamics and their effect on peatland functioning provide important information for peatland management and preservation policies.
To investigate long-term fire history and its effect on peat accumulation and peatland vegetation succession we analyzed macroscopic charcoal and plant remains from peat cores from five boreal peatlands located in sporadic permafrost zone in western Canada covering the past 1500 years. In addition, record of most recent fire events were derived from fire scars and documented fires on study area for the last 200 years. The regional long-term peatland fire patterns was examined by pooling together macroscopic charcoal records and calculating abundance of charcoal particles of each sample for each 100-year period over the last millennia.
All studied sites, except a northernmost palsa bog, demonstrate repeated fires throughout the study period suggesting that fires have been integral part of these peatland ecosystems in Western Canada. Compiled charcoal records indicate peak in fire activity with highest abundance of charcoal for the period from 1300s to1600s. Both, charcoal records and fire history from fire scars, suggest decreasing fire activity during the last two centuries. The clear and consistent post-fire increase in the abundance of *Sphagnum* mosses suggest relatively rapid recovery of the peatland ecosystem after burnings.

The regeneration pattern where pre-fire vegetation repeatedly recovers suggests that in long-term perspective fires may not necessarily have negative effect on peat accumulation. In conclusion, peatlands could remain as effective carbon sinks, if their natural state is preserved.

Holocene development, carbon accumulation, and fire regime characteristics in boreal peatlands

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Peatlands are the largest terrestrial carbon store on the planet, storing almost one-quarter of the global soil organic carbon stock, with 90% of this store residing in northern (boreal and subarctic) peatlands. However fundamental questions remain regarding the carbon sequestration potential of boreal peatlands in response to rising atmospheric temperatures, shifting precipitation patterns, and increasing frequency and severity of fire events. To understand how this carbon stock may respond to changing climate and fire risk, it is vital to understand the impact of past climate changes on peatland carbon accumulation.

This paper seeks to improve our understanding of peatland carbon dynamics in response to climate change in peatlands of Finland and European Russia. Considering their vast carbon stock, boreal peatlands are still relatively understudied, particularly for multiproxy studies. This is particularly true for European Russia which remains poorly studied and is largely absent from global syntheses on peatland dynamics. Further, peatlands in Finland are an excellent model ecosystem to study carbon dynamics and its relationship to climate, as they largely possess an undisturbed development history.

This paper addresses the knowledge gaps highlighted through a high-resolution, multiproxy, palaeoecological approach that will attempt to disentangle the drivers of carbon accumulation and reconstruct fire regimes across representative mire types for the boreal region. Four sites are under investigation, namely an ombrotrophic raised bog, an oligotrophic forested bog, a poor fen, and an aapa mire. To achieve this, a suite of established (plant macrofossils, testate amoebae, pollen, charcoal) and emerging (Raman spectroscopy) palaeoecological techniques are being employed. Raman spectroscopy has been extensively applied to charcoal material from modern soils, yet has the potential to provide insights on burning intensity during fire events. In particular, it may be possible to disentangle the effects of fuel type and moisture content on burning intensity and subsequent carbon losses. To date only one study has utilised Raman spectroscopy to reconstruct relative changes in burning intensity from peatlands and therefore this research provides the opportunity to explore a novel technique. The palaeoecological reconstructions will be complimented with robust Bayesian-age modelling chronologies, developed using ^{210}Pb and AMS ^{14}C derived dates.

Three peatlands – three stories of carbon accumulation: a case study from central Europe

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Peatlands, thanks to their capacity to capture CO_2 and long-term storage of organic carbon, play an essential role in the global carbon cycle. To better understand the patterns in carbon sequestration in time (the last ± 1500 years) and space, we reconstructed peat carbon accumulation rates (PCAR) in three peatlands (Jaczno, Głęboczek and Pawski Ług bogs) situated along the west-east gradient of northern Poland. Absolute chronologies retrieved from the Bayesian age-depth models based on high-resolution ^{14}C AMS dating provided good time control, whereas the selected time interval spanned a broad spectrum of human activity including population changes, from a major decline during the Migration period until the demographic explosion after the Industrial Revolution.

As our study aimed to find factors responsible for changes in carbon accumulation, we juxtaposed the obtained results with pollen, testate amoebae, plant macrofossil, and charcoal data. The results show that the investigated peatlands vary regarding local environmental conditions, patterns of development, vegetation and fire activity. The Głęboczek peatland (N Poland) is characterized by highly unstable environmental conditions, affected by numerous fires in the past. The Jaczno peatland (NE Poland) revealed relatively stable hydrological conditions for almost 900 years (from 1400 to 500 cal. BP), with generally high water levels and only several fire episodes, whereas Pawski Ług (W Poland) experienced an abrupt vegetation shift connected with the stabilisation of hydrological conditions and was almost not affected by fires. The highest PCAR was recorded in the Pawski Ług peatland (maximum = 271.3 g $C/m^2/yr$ and mean = 79.64 g $C/m^2/yr$). By contrast, another extreme was revealed by the Głęboczek profile, with a minimum equal to 2.63 g $C/m^2/yr$ and a mean 37.29 g $C/m^2/yr$. The Jaczno peat bog accumulated carbon with a mean rate of 74.6 g C/m2/yr, a maximum reaching 114.58 g $C/m^2/yr$ and a minimum equal to 18.22 g $C/m^2/yr$. Generally, the PCAR values were higher in the *Sphagnum*-dominated sections of the profiles with high shares of mixotrophic testate amoebae, unless fire hampered the process of carbon sequestration.

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Boreal and subarctic Canadian peatlands have accumulated large amount of carbon during the 20th century

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Northern peatlands constitute one of the most important terrestrial reservoirs of organic carbon (C). In Canada, peatlands in the boreal and subarctic biomes cover nearly 11 million km^2 and contain approximately 103-184 Pg C. This stock represents five times the C estimated to be stored aboveground in the Canadian boreal forest. Within the last few decades, northern Canadian high-latitude regions have warmed more than twice as fast as the global average and this trend is expected to continue in the future. While methane emissions are projected to increase with permafrost thaw, recent studies suggest net gains in peat accumulation and vegetation biomass associated with longer growing seasons and warmer temperatures. In order to evaluate the potential changes in carbon accumulation since CE 1900, we quantified C stocks from 182 individual peat cores from the high-boreal and subarctic biomes of Canada. Results show that the C stock accumulated since 1900 CE between the peatlands of the two biomes are not significantly different. However since CE 1980, the ACAR (apparent carbon accumulation rates) and related C stocks in the subarctic biome where permafrost is degrading, have exceeded those from non-permafrost sites as peat accumulation (namely *Sphagnum*) increases with thaw. While the overall C balance and future sequestration rates remain uncertain, our results show that altered post-thaw landscapes favored an increase in peat and C accumulation during the 20th century. Due to the irrecoverable nature of the existing peatland carbon sink, the potential emissions offset from increased productivity, especially in relation to permafrost thaw, needs to be further investigated. A better quantification of the net carbon budget from the high latitudes ecosystems including plant productivity will help to improve climate-carbon cycle feedback models.

Searching for a missing nexus: long-term response of the microbial peatland food-web to critical environmental transitions in the last 1500 years

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Soil microbes like algae, fungi and testate amoebae, stored in the peat, represent soil food web and enable the reconstruction of complex ecological networks. In this study, we assume that soil microbes (e.g., algae, fungi and testate amoebae) stored in the peat represent soil food web and enable the reconstruction of complex ecological networks. In the past, these networks were affected by abrupt shifts in hydrology, chemistry and vegetation. Hence, our study aims to [1] explore past centennial food web snapshots during the last 1500 years, [2] identify links between non-pollen palynomorphs (NPPs) and testate amoebae (TA), [3] search for the missing links between TA and NPPs, [4] relate food web snapshots before and after the peat fire, and [5] assess the trajectory of the post-fire recovery of the peatland. We wanted to answer how food webs changed over a long-term scale, significantly how microbes responded to peatland fire, as fire is often connected with the increasing human impact leading to intensive land-use changes. We chose a peat profile from Northern Poland (Głęboczek peatland) to track the complex changes in microbial communities in the context of the regime shifts connected with wet/dry/fire transitions *in situ* and around the studied peatland. The site, Głęboczek peatland, was formerly studied in the context of the 6500 years of ecological and archaeological history in a lower resolution. The top 1 m part of the profile, sampled in 1-cm resolution, revealed a transition from fen to bog and then a shift into a burnt peat section and hiatus. The high-resolution data shows a considerable change in agglutinating testate amoebae community after the fire, suggesting openness and soil erosion with the input of the organic matter from the surroundings. NPPs and plant macrofossils indicate the wetness change and fire event. This study inspired us to question how to recognize local peat fires and better understand the past peatland response to the recent extreme stress, recovery and resilience.

Topographic and climatic controls over peatland types and their distribution on the Tibetan Plateau

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The Tibetan Plateau (TP) hosts a variety of mountain peatlands that are sensitive to environmental changes. However, we lack a basic understanding of environmental factors controlling the peatland distribution in the region. Here, we use a bioclimatic envelope model (PeatStash) and environmental analysis that utilise three peatland data sets from the well-studied Zoige peatland complex, all peat sites described in the literature across the TP, and an existing global peatland map (PEATMAP) to investigate major drivers of peatland distribution in the TP. Our results show that soil moisture and slope are key factors for peatland formation and persistence. Most peatlands captured by PEATMAP are in valley and flat areas (slope <5°) with sufficient soil moisture (Moisture Index (MI)>0.5) and mean annual temperature between -5 and 2℃. Also, we use the peatland complex in the Zoige region to ascertain the environmental space of this peatland type, as these peatlands are well-studied and mapped. The Zoige peatlands are distributed in regions with a gentle slope (<2°), mean annual temperature between 0 and 2℃, and MI greater than 1.7, which is much narrower environmental space than that from PEATMAP. We then use these thresholds to constraint the climate envelope model and to predict future changes in peatland distribution. Our results show that the climate envelope for Zoige peatland complex will shrink greatly under scenarios of low-to-high warming scenarios (SSP1-2.6 and SSP5-8.5). Modelling peatland distribution in the entire TP remains challenging because: 1) gridded climate data from limited observations are not sufficiently accurate, owing to the complicated topography; 2) different types of peatlands are characterised by different topographic, hydrologic and climate factors that add an extra layer of complexity; 3) PEATMAP for the TP region is inaccurate in many locations, presenting both false positives and false negatives. Improved peatland mapping with sufficient ground-truthing is urgently needed in order to understand drivers of peatland distribution in the TP, to make an assessment of carbon storage and other ecosystem services, and to predict the effects of climate change on these important ecosystems.

Recent changes in vegetation and testate amoebae in a subarctic fen

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Northern peatlands store currently 415 Gt carbon (C), yet they remain a poorly understood feature in the current climate models. Increasing temperature and longer growing seasons may increase C sequestration and accumulation, but peatland drying recently observed throughout Europe, as well as in subarctic Russia and Canada, might have the opposite effect. Predicting the future of peatland C storage is complicated by changes in peatland vegetation: shrubs and trees are known to benefit from drying at the cost of mire forbs and mosses, which may lead to a transition from an open peatland into a closed forest within a few decades. This enhances decomposition, leading to C loss from peat, but it may be compensated by increased site-level photosynthesis and tree-biomass production. Enhanced fen-bog-transition has also been reported as a possible response to the drying and warming. As bogs tend to accumulate more carbon than fens, this could increase C accumulation. However, Sphagnum overgrowth of fen habitats has risen worries about possible biodiversity loss.

We will use paleoecological proxies – plant macrofossils and testate amoebae – to quantify changes in Lompolojänkkä peatland during the recent past. Climate change has been suggested to be the primary cause of drought-related changes in peatlands, but most of the studied peatlands are also affected by land-use originated anthropogenic impact. Lompolojänkkä is an ideal study site, as it is situated in a remote, scarcely populated area, where meteorological records are anyways available.

Four peat cores were collected from Lompolojänkkä mire margin in August 2020. Plant macrofossils were analyzed from the peat cores at 1– 4 cm intervals and testate amoebae at 1 – 2 cm interval. Pb-210 and C-14 dating methods were used to establish the chronology. We will show the changes observed in the plant and testate amoeba communities in Lompolojänkkä mire margin, and compare our dated peat records with the meteorological data from the site. Based on this knowledge, we interpret the implications for the mechanisms behind climate-induced changes currently observed in many northern peatlands.

Relationship between fire and mining activities over the late Holocene in a peat sequence in Northern Romania

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Relationship between fire and mining activities has consequence such as deforestation and mining, which overlap climate change, can cause changes in fire regimes and potentially increase the risk of fires, threatening vulnerable landscapes. The sedimentary charcoal is used for reconstructing regional changes in fire regime and anthropogenic effects of historical mining and local soil and bedrock erosion was also reconstructed using elemental geochemistry, magnetic mineral properties and particle size analysis. we analyzed sedimentary macroscopic charcoal morphological on sediments from the Taul Mare (TG) peat bog, in Lapus Mountains, northern Romania. Principal component analysis (PCA) was used to compare intensity in fire regime, charcoal accumulation rate (CHAR), geochemistry, magnetic mineral properties and particle size using PAST4.11 software. In late Holocene proxy may be interpreted as reflecting climate change caused by anthropogenic activity in special mining having consequence in landscapes with changes in fire regime. To understand the relationship between fire and mining activities, we surveyed published archaeological studies and traces of human settlement. The main results of PCA converge to conclude the following: fire activity increase following anthropogenic activities in the study area; increases in wildfire have generally been accompanied by episodes of increased landscape openness and expanded pastoral activities; the study area followed the mid-altitude mountains and proximity to landscape resources, pasture and mining. Temporally variation in fire severity may reflect climate changes (as shown by published regional palaeoclimate reconstructions) with, for example, warmer and drier condition. In conclusion our results show direct connection with statistically significant between fire severity and heavy metal concentration and direct link between fires and erosion (regardless of severity). This study offers information about previously unstudied environmental history in lowlands mountains, of the Northern Carpathians and emphasizes the importance of studies what can improve our understanding of the fire regime caused by mining activities.

Holocene development, functioning and decline of a Central European alkaline fen ecosystem

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$CaCO_3$ depositing alkaline fens host many endangered species of plants and animals and act as an important carbon sink. These unique peat-tufa accumulating ecosystems become rare due to natural environmental changes and human impacts. Proper protection and restoration measures of alkaline fens require their functioning in long temporal scales to be thoroughly understood. In the present study we investigate the development, functioning and decline of the formerly $CaCO_3$ depositing cupola alkaline fen in Makowlany (north-eastern Poland). We aim to recognise the major drivers of the fen ecosystem evolution. Two sediment cores collected from the top and slope of the fen cupola were radiocarbon dated and analysed for geochemistry (loss on ignition at 550 and 950°C, macro- and microelements, $\delta^{13}C$ and $\delta^{18}O$) as well as plant macrofossil and mollusc compositions. Peat deposition at the fen started ca. 11200 cal yr BP; however, tufa deposition did not begin until ca. 10700 cal yr BP when permafrost thawing in the area enabled the circulation of deep groundwater that provided the ecosystem with elements necessary for calcite precipitation. Change in the chemistry of the fen surface favoured plants and molluscs typical of alkaline fens, including mosses, e.g. Tomentypnum nitens and gastropod Galba truncatula. The most optimal conditions for calcium carbonate precipitation, and therefore the development of the alkaline fen ecosystem with Cladium mariscus stands persisted between 8800 and 5800 cal yr BP, which was an effect of high temperatures and humidity associated with the Holocene Thermal Maximum. The gradual decline of sedimentary $CaCO_3$ since ca. 5600 cal yr BP likely records the temperature drop in central Europe. The increasing thickness of the sediments accumulated at the cupola could have also disabled the artesian waters from reaching the fen surface. Since then, brown mosses have been replaced with vascular plants.

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Bog pine dendrochronology related to peat stratigraphy: reconstruction of the Holocene palaeoenvironmental changes in the territory of Poland on the basis of dendrochronological studies of subfossil trees and peat multiproxy analysis

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Within the European peatlands subfossil tree trunks occur buried in organic deposits.
Identified on the basis of dendrochronological analysis, the phases of dying-off trees growing in peatlands as a result of long-term rise in water level, as well as the phases of trees germination during the peatlands drying, reveal the relationship between these phenomena and the phases of climate humidity growth/climate drying during the Holocene.
Currently, comprehensive studies encompass 9 peatland sites in Polish territory: Grel and Zawadowskie peatlands in the Carpathians, Podemszczyzna and Mosty peatlands in Southern Poland, Napoleonów in Central Poland and Imszar, Budwity, Rucianka and Krakulice peatlands in the Northern Poland. Some of them were formed during the Late Glacial (Podemszczyzna, Imszar), whereas the youngest one (Rucianka mire) was formed at the beginning of the Subatlantic Phase of the Holocene. Within all sites, mainly subfossil wood of bog pine (Scots pine: *Pinus sylvestris*) was used for dendrochronological analysis (within three sites there were also subfossil oak trunks *Quercus* sp.). On the basis of the wiggle matching method, several floating chronologies for bog pine were elaborated. The oldest of them (9980-9830 cal. BP) was compiled for the Podemszczyzna peatland in the Sandomierz Basin. Younger floating chronologies of bog pines from various peatlands in Poland have been compiled for the periods: 6790-6530; 4255-4060, 3130-2820, 2930-2290, 2170-1860 cal. BP. The youngest chronology (183 years), the end of which was dated at around 1179-1057 cal. BP, was developed for the Mosty peatland.
The results of dendrochronological analysis have been compared with the results of multi-proxy analyzes of peatland deposits, including pollen and non-pollen palynomorphs (NPPs), Cladocera, Diatoms, macrofossils and geochemical analyzes. For Rucianka and Budwity sites analysis of Chironomidae was also performed. These analyzes, supported by numerous ^{14}C radiocarbon dates, showed that the beginning of trees germination and colonization of peatlands by bog pines occurred during the phases of the climate drying, while the mass dying-off trees in peatlands took place during the phases of the climate humidity growth in the Holocene.
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Peat sequences of the Somme Valley (Northern France): a 14,000 years long record of climate and anthropogenic forcing factors on bottom valley fluvial environments

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At the scale of northwestern Europe, the valley bottoms of the River Somme basin make remarkable wetlands characterized by a significant fluviogenic peat accumulation (4 to 6 m on average). These fluviogenic peat (fen) sequences provide outstanding archives to describe the environmental evolution of northwestern France over the last 14,000 years. They are also fragile environments forming huge carbon sink. In this context, a research initiative has been initiated to highlight the respective roles of climatic and anthropogenic forcing factors (drainage, slope soil erosion) on peat formation/degradation processes and the modification of the related fluvial environments. The study is based on two stratigraphic transects of the valley (about 600 m each) based on more than one hundred manual boreholes and mechanical corings. The reconstruction of both sedimentation dynamics and palaeoenvironments evolution is based on a multiproxy approach combining sedimentology, geochemistry, palynology, and plant macro-remains identification, supplemented by forty-two ^{14}C dates. This work reveals that the first peat deposits were restricted to channel filling at the beginning of Lateglacial (14.6 - 14.0 ka cal. BP). This first peaty event was then interrupted during the Younger Dryas by the deposition of highly calcareous overbank silts ($CaCO_3$ > 40%) in the whole alluvial plain. Typical peat formation with high TOC values (> 45%) then restarted at the beginning of the Preboreal period around 12 ka cal. BP and rapidly extended to the full valley bottom (0.07 cm/year). During the Subboreal, the reactivation of the river flow is then indicated by the development of a deep meandering channel progressively filled in with laminated silty-organic deposits and a slower peat accumulation rate in the alluvial plain (0.03 cm/year). These modifications are contemporaneous with the generalized opening of the landscape (palynology), associated with the acceleration of anthropic erosion processes on the slopes during the Sub-Atlantic (2.9 ka cal. BP). Since the end of the Middle Age, organic silts fed by the erosion of loess soils have rapidly buried the peaty system, which is today essentially inactive and fossilized.

Peatland development in East European forest-steppe

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The East European forest-steppe forms a transition zone between humid broadleaf forests and arid steppes. Hot and dry summers do not favour peatland development, which more depends on the inflow of ground water. Consequently, genesis and development of forest-steppe peatlands are highly variable and strongly depend on local conditions. Forest-steppe peatlands especially *Sphagnum* dominated systems provide wide range of ecosystem cervices; therefore, have high nature preservation values. However, today they are facing frequent droughts and increasing agricultural intensification, very likely leading to their disappearance in the nearest future. The patterns of peatland formation in the East European forest-steppe since the late glacial are poorly studied. In order to close this gap, we investigated several mires in Kursk (Russian Federation) and Kharkiv (Ukraine) regions. Radiocarbon dated archives were studied for pollen, non-pollen palynomorphs, botanical macroremains, loss-on-ignition, micro- and macrocharcoals. Although some archives cover the last 15,000 years, formation of few peatlands (>30% of organic material) began in the Holocene. Starting points of organic accumulation vary considerably from 9000 yrs BP to the last few centuries. An increase in peatland development and carbon accumulation in the study region occurred in the late Holocene coinciding with an onset of the Holocene climate cooling and spread of broadleaf and pine forests, indicated by pollen data.

Session 158: The geomorphic signature of marine and continental Quaternary deposits

Timescales of erosion and sediment transport at the edge of the Colorado Plateau, USA: connecting upland sediment fluxes and down-valley fluvial processes over multiple glacial cycles

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Understanding the spatiotemporal scales of sediment production and transport across a landscape provides insight on the fidelity of stratigraphic records and is essential for predicting how surfaces we depend on may respond to climatic change. Unraveling the myriad processes that shape earth's surface through geologic time requires integrating various, widespread, and well-dated records. Here, we present a sediment core record of clastic flux into Stoneman Lake, Arizona, USA, a small (3.5 km^2), basaltic catchment high (2050 m) on the edge of the Colorado Plateau. End-member modeling of particle size data to identifies three sub-populations, fine dust, coarse dust, and local alluvium, whose modes are influenced by the weathering and transport histories of their source material. In combination with age control and density measurements, the volumes of these sub-populations are used to calculate the flux of each sub-population into the basin since ~ 230 ka, a period spanning the last two glacial cycles. Alluvial flux is high during warmer and dryer interglacials (Holocene, MIS 5 and 7) and increases dramatically following glacial terminations. Accumulation rate of the loessic (coarser dust) end-member increases during glacial episodes (MIS 2, 4, and 6) and likely corresponds to upwind fluvial aggradation occurring 25 – 45 km downslope to the south and southwest in the middle reaches of the Verde River. This concurrent record of sediment flux in an upland setting and activity in a downslope fluvial system suggests hillslope sediment mantles are produced during cooler and wetter glacials on 10^4-year timescales, stabilized by extensive forest canopies. Following a transition to warmer and dryer interglacial conditions, forests migrate and precipitation modes change, increasing runoff and liberating hillslope sediments on 10^2 -10^3 year timescales. Much of this sediment is stored in tributaries and doesn't feed into downslope fluvial systems until tens of thousands of years later when wetter glacial conditions increase discharge and tributary erosion. By exploring the temporal scale of sediment movement on the southwestern edge of the Colorado Plateau, we see that Quaternary climate changes act as a sediment pump, affecting sediment storage and the pace of transport between hillslopes, tributaries, and rivers.

Climate driven paleo denudation rates evolution in Madagascar and associated sediment sourcing to the Mozambique Canal since 900 ka.

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Denudation is the sum of chemical alteration and physical erosion. It is a key parameter controlling the evolution of the Earth's surface, the production of soils, the stability of relief or the evolution of orogens. Through silicate alteration and sedimentary fluxes that control the burial of organic carbon, denudation rates can influence climate. In turn, climate has a strong control over denudation through a number of processes such as precipitation or vegetation distribution. In order to understand the past evolution of the Earth's surface and to better predict future changes that will affect our habitat, it is necessary to constrain links that exist between climate and denudation. This requires precise quantification of past denudation rates.

At mid to high latitudes, denudation rates are strongly controlled by glacial and periglacial processes. Tectonic activity also has a strong impact on denudation, especially in rapidly uplifting orogens. Most studies reconstructing paleo denudation rates however, have concentrated on tectonically active and/or glaciated regions during the quaternary. To better comprehend the climate/denudation system, we propose here to reconstruct paleo-denudation rates from cosmogenic radionuclides in a region that has been affected neither by glaciers nor tectonic activity during the Quaternary, Madagascar. We measure cosmogenic ^{10}Be and ^{26}Al in quartz grains of turbidite layers from a marine sedimentary core that has been dated between 50 and 900 ka, and that was drilled on a terrace of the underwater Tsiribihina valley, in the Mozambique Canal. The ^{10}Be analysis of this core allows documenting paleo-denudation rates over several glacial-interglacial cycles, while the $^{26}Al/^{10}Be$ ratio gives us constraints on burial ages.

In order to investigate the sources of the terrigenous sediments brought from Madagascar to the Mozambique Canal during the past 900 ka, we use εNd, which is an efficient source tracer for ancient lithologies, such as in Madagascar (Mesoarchean to Neoproterozoic), as well as heavy mineral analysis/counting. Evolution of sediment sources also provide us with valuable information on the evolution of climate and precipitation in this region.

This integrated approach allows us to reconstruct climate affected paleo-denudation rates from a well delimited region during the Pleistocene.

Preliminary sectorization of the Zadorra drainage basin (Álava, Northern Iberia) evidencing Quaternary fluvial evolution

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The Ebro River, which constitutes one of the most ancient fluvial systems of the Iberian Peninsula (ca. 7.5-5.3 Ma), which onset is somewhat related with the Messinian Sea-level drop. Is the main fluvial catchment of N-NE Spain flowing into the Mediterranean from pre-Quaternary times. This study focusses on one of their main tributaries in its headwaters, the Zadorra River (Basque Country) which is 78 km long, with a catchment area of 1,398 km^2. According to preserved sedimentary deposits and geomorphological features, four distinct sectors) can be differentiated within in the present Zadorra drainage basin. Each sector reflects a particular evolutionary stage of the Zadorra fluvial system. From ancient to modern are: Sector 1 (415 km^2) comprises the present headwaters area of the Zadorra Basin and still preserves relatively large alluvial fans surfaces at basin margin locations, north and south. Here fluvial incision develops parallel to the regional strata bedding (N120E), generating a succession of “ridge and valley” structural reliefs by differential erosion in Cretaceous folded series illustrating a case of topographic rejuvenation. Sector 2 (343 km^2), to the north, outline to elongate N-S river basin heading in the higher reliefs of the Cantabrian-Basque Mountains, showing fluvio-karstic structures and periglacier-glacier landforms in the headwaters. In Sector 3 (141 km^2), at basin centre, the axial drainage shows a meandering pattern dissecting Pleistocene-Holocene lacustrine and distal fan deposits recording a previous semiendorrehic stage of the basin. However, its southern margin records the at least three stepped alluvial fan surfaces, the highest one at + 110 m above the Ebro River. Sector 4 (152 km^2), to the south, constitutes the present fluvial outlet towards the Ebro valley. It is constituted by a N-S transverse valley cutting the east-west structural reliefs bounding the Zadorra basin by the south. This represents the eventual capture of the rest of the afore described zones. Highest terraces recorded in this sector locate at + 60 m above the Ebro River, suggesting a Lower-Middle Pleistocene age for the eventual capture of the basin. Further studies on Quaternary landforms and geochronological analysis will help to refine a more detailed basin evolution.

A first look into new Pleistocene sedimentary records from the Upper Rhine Graben

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Sedimentary records containing evidence of past ambient conditions, flora and fauna, and geomorphic processes are the key to understanding and quantifying environmental change. Unfortunately, the preservation potential of deposits is typically low in terrestrial environments, and the resulting fragmentary, puzzle-piece character of continental sedimentary archives significantly hampers detailed reconstructions. This highlights the importance of, ideally long-lived and regionally significant, terrestrial sediment sinks.

One such sink is the Upper Rhine Graben (URG), a rift basin extending over >300 km from Basel, Switzerland, in the South to Frankfurt am Main, Germany, in the North. The URG has been subsiding since the early Cenozoic and has been filled by a kilometre-thick sediment sequence including up to ~500 m of Quaternary strata. Being fed by the Rhine river and its tributaries, the URG collects deposits derived from the Alps as well as from the graben shoulders including the Vosges mountains and the Black Forest.

We investigate the Quaternary sediment fill of the URG based on a set of drill cores spanning a longitudinal section of ~175 km length. In these cores diverse successions are recovered, including (glacio-)fluvial gravels and sands but also fine-grained lake sediments and loess as well as diamictic deposits. They are valuable windows into the past, and provide information on mountain glaciations, erosional and sedimentary processes, past environmental conditions and ecosystems.

Characterization and the volumes estimation of overflow deposits by a fossil branch of the Rhône, Bras de Fer (France), at the Little Ice Age through geomatics, sedimentology and geophysical tools

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The extent and spatial footprints of glacial periods can be estimated from river sedimentary deposits. Thus, the morphology of the Bras de Fer, paleochannel of the Rhone, is the outcome of the climatic and hydraulic conditions of the Little Ice Age. The crevasse splay deposited on its right bank, and the palaeoforms of river braiding reveal a strong hydraulicity of this fossil distributary of the Rhone delta during its brief operation (1582-1711), whose dates are known through historical documents (Pichard and al., 2014).

The combination of GIS, sedimentology and geophysical methods facilitates the qualitative and quantitative study of river palaeoforms. The objective was achieved through the acquisition of very high-resolution, open-access spatial data (IGN, 2021), as well as improved sediment (Dean, 1974; Blott and Pye, 2012) and geophysical (Demory and al., 2019) characterization methods.

Quantifying of sedimentary volumes of the Bras de Fer is carried out by crossing a thin DTM (50 cm*50 cm) with different methods of stratigraphic recognition (core, ERT, trenches). Sedimentology analysis, magnetic susceptibility, C14, and OSL dating were used to characterize the deposits and define their age.

The stratigraphy of the sedimentary facies, combined with the particle size and organic matter (OM) and CaCO3 levels, specify the sedimentation processes of the area. The crevasse splay has coarser sedimentary fractions, with less OM and more CaCO3 than the anterior and posterior strata. Overall, the material applied is fine, ranging from fine sand to coarse silt, and contrasts with the particle size of the channel bed sediments.

The spatial distribution of accumulated sediments is determined by combining quantitative and qualitative data. A proximal-to-distal particle size gradient of the overflow materials was established as a function of the distance to the distributary palaeochannel, the Bras de Fer. Sediments are deposited preferably in the immediate vicinity of the bank rise, while distal deposits are mainly composed of coarser particles showing more hydrodynamic episodes.

Source-to-sink relation between the Romanian Carpathians and the Lower Danube Basin: an overview based on geochronology, lithology and geomorphology

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During the last 16 Ma, the Lower Danube course changed several times due to the geomorphological processes including the regional sea level changes, local tectonics, and sedimentary landscape evolution. The analyzed Quaternary sediments from the river deposits bring up-to-date strong evidence of the most eroded geological formations belonging to the Southern and Eastern Carpathians.

The recent Lower Danube sediments between Iron Gates Dam area and the Danube Delta are generally represented by clay, silts and fine to medium sands. We tried to identify the connection between the Lower Danube recent sediments and the main source of these sediments based on the detrital zircons (DZ) geochronology tool, lithology and tectonics factors.

A highly ranged spectrum of ages was identified using U-Pb geochronology on DZ, in the Danube River. Most of the DZ exhibit three major groups of ages: i) Cambrian-Ordovician, associated to back-arc basins and island arcs, linked to the Peri-Gondwana subduction (600 – 440 Ma); ii) Lower to Middle Carboniferous, from magmatic and metamorphic Variscan units (350 – 320 Ma), represented by dominant peaks in most analyzed samples; iii) Upper Cretaceous to Tertiary, younger than 100 Ma, possibly related to the Southern Carpathian Late Cretaceous Banatitic arc and to the Neogene volcanism of the Eastern Carpathians and Apuseni Mountains. Moreover, for the Lower Danube western tributaries the main sources of the DZ are the high-grade metamorphic rocks characteristic for the Danubian tectonic units of Dacia mega-unit. Some larger tributaries from the Lower Danube easternmost part show temporal disperse peaks on the DZ geochronology, feature probably reflecting successive processes of recycling. Notably, the most representative sources of DZ identified in the samples from easternmost Lower Danube tributaries are the Variscan metamorphites.

We conclude that the main source for Quaternary sediments of the Lower Danube are the metamorphic rocks of the Southern Carpathians, located between the Iron Gates and the Olt River basin. In the eastern Lower Danube, on the Romanian territory, a mixture of igneous, metamorphic and sedimentary rocks has been pointed out.

Flexure area, the gateway of the morphology and sedimentary structures of the upper slopes – NW Black Sea case

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The flexure area of a marine basin is both the gateway and the witness regarding the sediment transport and deposition of sediments on the upper continental slopes. Usually in this area most of the canyons and channels are indented onto the outer shelf and from where the sediment supply is further delivered downslope. Here is also the place where the cold water cascading phenomena deliver large volumes of denser water to the continental slope. The amount of sediments mixed in the water mass is function of how far is the coastal area, the hydrographic network of the surroundimg land, currents and waves regime. The flexure zone and its adjacent areas are many times prone to dynamic phenomena as are tectonics and fluids expulsions. The convolution of the above mentioned environment and phenomena produces a diverse morphology and structures of the sedimentary bodies existing in the flexure and upper continental slope areas. The NW Black Sea is a very interesting and good example for all the phenomena mentioned above and due to several oscillations of the sea level the resulted morphologies and sedimentary structures are even more complex. In this part of the Black Sea the nowadays shelf is the widest and are present important features in terms of morphology and structure, as the Paleo-Danube canyon, other secondary canyons and large sedimentary edifices of the Danube and Dnieper deep sea fans. The Last Glacial Maximum – LGM lowered the water level just in the area of the present flexure zone and because of this at least one couple of regression-transgression has taken place. Specific morphologies and structures have been formed, that testify the erosion, construction of new system tracts, as well as features produced by the phenomena of fluid dynamics. The outer shelf area has a palimpsestic character due to several sea level changes that made that zone subaerial and then swept by regressive-transgressive waters. The paleo-hydrography of the subaerial times was complex and brought sediments to feed the flexure area and the upper slope. The specific morphology of the flexure area influenced the downslope delivery of water masses and sediments.

Mt Śnieżnica landslide fen and its palaeoenvironmental record – reconstruction based on geochemical proxy and radiocarbon dating

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In the present study, we analyzed a 4.4-m deep core excavated from the fen formed within the landslide body on the northern side of Mt. Śnieżnica in the Wyspowy Beskidy Mountains, the Outer Western Carpathians, southern Poland. In total, we analyzed 405 samples in terms of 29 geochemical components (e.g., nitrogen (N), carbon (C), sulphur (S), and the total organic carbon (TOC)) and physical properties, namely particle-size distribution, loss on ignition (LOI), and microcharcoal content. Additionally, to establish geochronology, we dated 27 samples of different biological materials using the Accelerator Mass Spectrometry radiocarbon method. A detailed examination of plant macrodetritus and wood anatomy supported our interpretation based on the geochemical data. The Mt. Śnieżnica landslide has probably formed ca. 14,000 cal BP in the first phase of the Allerød Interstadial. For almost 9000 years, there was no accumulation of organo-mineral material. At ca. 4400 cal BP, peat accumulation commenced. The peat accumulation begins with the global 4.2 Bond event of cold climate conditions. After another ca. 2000 years, the core sediments were dominated by limnetic mud, suggesting aquatic conditions in the landslide depression. This sudden shift in sedimentation characteristics is loosely linked to the boundary between the Subboreal and Subatlantic phases (ca. 2500 cal BP). The apparent dichotomy of the depositional record agrees with the reconstructed climatic conditions during the second part of the Holocene. Up to 3000 cal BP, the regional climate was warm and humid, which allowed fast biomass production and hillslope stabilization by trees. Forest fires occurred only at the beginning and end of this period (4400-3000 cal BP). After 3000 cal BP, the regional climate became cool and dry. In this period, we found evidence of intensified erosion, but it was unrelated to forest fire activity.

Sedimentary record of Holocene cave clastics as a model of an interglacial sequence? Insight from caves of Polish Jura (Poland)

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In many regions, including the Central Europe, the research on clastic cave sediments of the near-entrance facies has been focused so far on Pleistocene sediments. This bias was partially due to researchers' interest in the Palaeolithic, and partially due to the fact that Holocene sediments are usually poorly preserved, as a result of e.g. commercial exploitation of the deposits in 19th and 20th centuries. In Poland, famous researchers of cave sediments, such as S. Krukowski, W. Chmielewski and others, left the Holocene strata nearly without any comment. However, the excavations in the recent years have shown that the Holocene cave sequences show great scientific potential. In these sediments we find a record of climate change during the past several millennia, geomorphic processes, changes in fauna and vegetation, the anthropopressure, and the development of culture. Moreover, following the actualism approach, the Holocene sequences may be regarded as a model of an interglacial series; especially the sediments of the Lower/Middle Holocene, non-affected by the development of civilization, may be used for such approach.

In this paper we present the key and well-dated sequences of the Holocene near-entrance facies of cave deposits from Polish Jura (including: Shelter in Smoleń III, Żarska Cave, Perspektywiczna Cave, Cave above the Słupska Gate, and others). We search for common (thus, regional) and atypical (local) features in the sedimentary record and follow these correlations to formulate a regional scheme of the sedimentary sequence, including the main geomorphic events, weathering phases, and ecosystem changes. We also note any local deviancies in a sedimentary record, representing site-restricted disturbances caused for example by local topography, human impact and animal activity. Finally, we apply this litho-, allo- and climatostratigraphic model sequence to the Pleistocene sites in a search for analogous records. Of our particular interest are long profiles of Biśnik Cave, Nietoperzowa Cave, Ciemna Cave and Tunel Wielki Cave, where we may expect sediments from the last interglacials (MIS 5e, MIS 7, MIS 9).

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Landscape evolution in the Ganga-Sai interfluve in response to river dynamics and climate change via a meander cut-off lake of a plains-fed channel

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The floodplains lying to the north of the river Ganga in the Himalayan foreland basin act as transient storage for sediments derived from the Himalayan mountains. This fluvial terrain offers adequate groundwater supply and fertile fields to support the agricultural production and livelihood of a large population. The Ganga-Sai interfluve in the Central Ganga plains exhibits a broad suite of geomorphic features such as narrow meandering loops of streams, stretches of linear lakes representing sinuous abandoned channels and meander cut-offs, small ponds, and oxbow lakes. Regional and local-scale geomorphic mapping was carried out utilizing earth observation satellite imageries to comprehend the evolution of the linear array of meander cut-offs and oxbows in the Ganga-Sai interfluve. Results of the geomorphic analysis indicate that the belt of paleochannel remnants was formerly a part of the avulsed channel of the Sai river. Four stages of landscape evolution and development of various geomorphic features linked to channel migration in the Ganga-Sai interfluve region of the Central Ganga Plains between the Late Pleistocene and Holocene periods have been identified. Further, an oxbow lake (Baraila Tal) was chosen from this linear array of cut-offs, and three locations were excavated to examine the chrono-stratigraphic succession. Stratigraphic succession at Baraila Tal supported by sedimentology and stable isotope data from organic matter and micro-gastropod shells shows that this lake was previously a part of an active fluvial system, and the depositional environment transformed from a fluvial to a lacustrine system in response to geomorphic and climatic changes during the post-LGM period.

The Holocene graben of the Cotovelo River: a conspicuous active morphotectonic feature in the Brazilian Shield

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Despite being preserved of orogenesis since the Early Paleozoic, the Brazilian Shield had experienced episodic epeirogenetic uplifting during the Phanerozoic, following Mesozoic and Cenozoic tectono-magmatic reactivations. The progressive opening of the Atlantic Ocean, the uplift of the Andean Chain, the macro-doming of central Brazilian Platform, the tilting of the northern part of the continent toward the Amazon/Orinoco basin low and Caribbean Sea, and the South America plate rotating clockwise are large scale internal processes controlling the geomorphodynamic at continental scale. In this context, fluvial dynamics and deposits are important tools in the investigation of endogenous control of depositional and denudational events of low magnitude at local scale. Therefore, geomorphological, sedimentary, geochronological, and hydrological data were assessed in order to investigate the continuing low rate active tectonic throughout the Late Pleistocene and Holocene, on the Western Brazilian Atlantic Shield, taken the Holocene graben of the Cotovelo River low valley as case. This graben accommodates a well-defined Northeast-Southwest oriented floodplain, delimited by 30 m-high, aligned shoulders, corresponding to Upper Pleistocene terraces, and results from an intraplate rifting. Deeply weathered sandstones under humid tropical climate supply a huge sediment load to the channel, creating a meander-like river pattern confined to an asymmetrical sedimentary basin, pointing to ongoing subsidence along normal parallel active faulting. Right margin tributaries carry significant amount of sediments to the floodplain, in alluvial fans. Indirect evidences allowed to propose vertical velocities for the active faults in the area, for a time scale of several thousand years, that integrates a significant number of geomorphic features and drainage anomalies such as channel diversion, anomalous bends, very young flying terraces, asymmetrical sedimentation, compressed meanders, impressively high and rectilinear scarps, etc. Based on 13 absolute OSL dating values, and in the recent fluvial history, the average slip rate of the graben was roughly estimated in 0.8 m^{-1}/ky since the Late Pleistocene. Thus, the Cotovelo River graben is a strong evidence of recent tectonic reactivation in intraplate environment and represents a benchmark of continental tectonic significance that provide specific information about the dynamic of landscape in the Western Brazilian Atlantic Shield and Eastern South America.

The different Late Quaternary morphotectonic evolution of the two main peri-Tyrrhenian grabens: Campania and Sele river coastal plains (southern Italy)

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The Campania sector of the southern Apennines is characterised by two wide coastal basins, namely Campania, in the north, and Sele plains, in the south.

Both represent peri-Tyrrhenian half-grabens sharing common features such as i) NE-SW trending master fault systems in the NW border; ii) thousands of meters thick basin infilling and, iii) carbonatic bedrock downthrown up to 3-4 km b.s.l. The formation of such half-grabens is due to the Late Miocene extension, still active, that caused the opening of the Tyrrhenian back-arc basin.

Even if during the Early Pleistocene the stratigraphic and structural setting, that led to the shaping of the Campania and Sele coastal plains is similar, their Late Quaternary evolution is quite different. In fact, while the Campania Plain records subsidence since Early Pleistocene and the formation of volcanic complexes during the Late Pleistocene, on the other hand, the trend of vertical motion, from subsidence to uplift, changes along the Sele Plain during the Late Pleistocene as testified by i) incision and terracing of the alluvial fill at the mountain foothills and, ii) presence of raised marine deposits on the coast.

In order to better constrain the Late Quaternary morphotectonic evolution of both plains, an integrated morphotectonic and morphostratigraphic work was carried out by geomorphological analysis of high-precision topographic data (1:5.000 scale maps and 5-m DEM resolution), field work and analysis of subsurface data from former and new shallow borehole logs.

New data provide a better definition of vertical movements during the Late Quaternary in the Campania and Sele plains by a detailed definition of the coastline changes as a consequence of the tricky interaction between sedimentary infill and sea level fluctuations.

The largest system of LGM continental dunes of the Italian Peninsula: the Dunes of Belvedere – San Marco of Aquileia (NE Italy)

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Continental aeolian landforms and deposits related to Last Glacial Maximum climate conditions are typical features in Central and Western Europe, whereas they are unknown in the alluvial plains of northern Italy. Thanks to the analysis of aerial images, Lidar DEMs, Ground Probing Radar (GPR) profiles and field survey we identified a large system of dunes formed at the end of the Last Glacial Maximum in the coastal portion of the Friulian Plain, between the city of Aquileia and the Grado Lagoon. They are locally called "dunes of Belvedere–San Marco" and they cover an area of about 25 km^2, elongating in ENE-WSW direction. Their highest crests reach 10 m above sea level (asl), in contrast with the surrounding reclaimed coastal plain (-1 m asl). The deposits range from fine to medium-coarse sands, and concretions of cemented sand are abundant on the surface. In outcrops and GPR radargrams the cross sections document an internal structure made of few centimeters thick, 20-30° inclined foresets. They lay on top of the distal portion of the Isonzo River megafan, and their base and preserved top are radiocarbon dated to 21 ky cal BP. The new data allow to interpret the Belvedere – San Marco reliefs as a system of parabolic dunes, which currently represent the largest and most complex continental dune field in Italy. Moreover, the orientation of the dunes is concordant with that of Bora, a katabatic wind which blows in northern Adriatic and even today can reach peak velocity of 40 m/s. Similar winds, supported by the North European and Alpine ice caps could blow stronger and more frequently at the end of LGM and during the onset of deglaciation. Furthermore, the sparsity of vegetation due to the dry cold climate, and the large availability of sandy sediment, supplied by braided channels of the Isonzo River, created favorable conditions for the deposition of aeolian dunes. This discovery underlines the importance of wind-driven processes in the evolution of alluvial plain in northern Italy and suggests the presence of other continental dune systems with similar age, even on the present floor of the Adriatic.

The impact of Quaternary sea level changes on the development of depositional environments in the Kornati Channel (Adriatic Sea)

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The glacial-interglacial cycles that occurred during the Quaternary affected many present-day coastal areas due to the significant changes in sea level that accompanied each cycle. Silled basins are especially sensitive to these changes. Thus, our study focused on obtaining a new record of the paleoenvironmental and sea level variability in the Kornati Channel silled basin by using multibeam bathymetry and high-resolution seismic data in combination with sediment core information. The investigated basin is a protected natural area, located in the central part of the eastern Adriatic. It comprises several adjacent sub-basins with different sill depths and numerous small islands some of which are nowadays submerged. The landscape is dominated by a steep escarpment that extends to a depth of 90 m below the present sea level. These submerged geomorphic features, which strongly influenced the evolution of the Quaternary environments, are well depicted in the obtained multibeam data. We recognized transitions between marine conditions during the interglacial highstands of sea level and terrestrial environment developed during the last glacial sea-level lowstand. The late Pleistocene-Holocene transgressive phase was a brackish-water environment, formed due to the karst features present in the investigated area. Changes in the depositional environments in different sub-basins primarily occurred as a result of the connection or disconnection of the Channel from the Adriatic Sea via sills at present-day depths of 30 and 50 m. Multiple sediment cores gave abundant direct evidence of these changes, whereas seismic data enabled stratigraphic correlation and reconstruction of the spatial distribution of the deposited sediments. Our study contributed to the understanding of the complexity of past environments developed along the karstified eastern coast of the Adriatic Sea. Furthermore, we revealed one of the longest Quaternary sedimentological records in the eastern Adriatic. The assigned MIS 3 age of investigated succession is important because records of this age are relatively rare in general.

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Seismic-stratigraphy of Quaternary lowstand prograding wedges on the western margin of the Adventure Bank (central Mediterranean Sea)

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Based on recently carried out morpho-batimetric and high resolution seismic investigations, a large field of coastal prograding sedimentary wedges has been discovered and investigated along the north-western sector of the Adventure Bank in the south-west Sicily offshore.

The Adventure Bank is located in the north-western sector of the Sicily Channel and represents a wide shallow waters area with average depth of 70-100 m; along its northern margin, the shelf edge lies at a depth between 80 and 170 m, and it is scoured by a few canyons headscarpements (Mazara del Vallo canyons, Egadi Valley).

During the sea level lowstands related to the cyclic eustatic changes occurred in the middle-late Quaternary, the Adventure Bank formed a wide emerged plateau and, along its north-western margin, a stack of wedge shaped, progradational sedimentary units developed.

The observed sedimentary wedges are composed of large dipping strata which prograde seawards downlapping on an extensive marine-to-subaerial erosional surface; individual clinoform horizons are up to 15 m high and display tangential or sigmoidal geometry; parallel to the shelf margin elongation, individual wedge displays lateral continuity up to 4,5 km. The top of the prograding wedges is truncated by a sharp ravinement surface that, landward, is draped by a thin, up to 2 m thick, seismic unit of gently dipping reflectors.

On the whole, the entire package of progradational wedges consists of superimposed levels of prograding clinoformed units separated by main downlap surfaces, and its deposition accounted for up to 1,5 km frontal accretion of the continental shelf margin.

A sequence-stratigraphy analysis of this sedimentary prograding package and a comparison with similar and coeval stratigraphic setting of others Mediterranean continental shelf margins, suggest these prograding wedges accumulated in a coastal environment as forced regressive sedimentary bodies during falling and lowstand stages related to the late Quaternary glacioeustatic sea-level changes generated by global climatic changes. The growth of shelf margin wedges has been largely controlled by paleotopography of the bottom downlap surface and by location of sediment supply entry points.

Session 159: Human-environment interactions in coastal areas: new ways to learn from the past

Between medieval land reclamation and storm surges – reconstructing man-environment interactions in the Wadden Sea of North Frisia (Germany)

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The coastal landscape of North Frisia (Schleswig-Holstein, Germany) has a very changeful geomorphological past. What is nowadays part of the UNESCO world heritage “Wadden Sea” was once an extensive cultural landscape. Yet, intense medieval man-environment interactions not only caused a rapid transformation of the natural landscape but also caused an increased coastal vulnerability that finally led to a storm surge-related permanent destruction of wide parts of the region.

Until today, much of the cultural heritage of medieval North Frisia has been preserved in the tidal flats and provides unique insight to so far little understood aspects of land reclamation measures, settlement structures and man-environment-interactions. Our main objectives were therefore to reconstruct selected areas of the drowned landscape on a micro-, meso- and macroscale to identify natural processes as well as human interventions with the environment to gain a better understanding of the medieval coastal landscape, its complex development and final destruction.

We combined different geophysical prospections methods (magnetics, seismics, electromagnetic induction EMI, electrical resistivity tomography ERT) with Direct Push sensing (Hydraulic Profiling Tool HPT, Cone Penetration Testing CPT) and vibracoring to provide insights to the tidal flat’s subsurface that - together with sedimentary, geochemical and microfaunal palaeoenvironmental parameter (PEP) analyses – allow for a detailed geoarchaeological reconstruction of the medieval. The geochronological framework is based on radiocarbon dating, archaeological age estimations of diagnostic finds, dendrochronology and historical reports.

Our results provide new insights into medieval land reclamation, cultivation measures and settlement activities that exceedingly modified most of North Frisia’s natural coastal landscape and increased its vulnerability against storm surges. The successful application of this interdisciplinary research approach also allows an extrapolation of our results to other Wadden Sea regions. Our reconstructions can even be considered a striking example for potential effects of future extreme events. Finally, we emphasize the urgent need for further investigations, as the cultural heritage preserved in the Wadden Sea archive is in itself highly vulnerable and already affected by strong erosion.

The dynamics of blue carbon sequestration in the Magdalena River delta, Colombia

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Mangrove forests are unique tropical ecosystems that can sequester and store carbon (C) very efficiently. They play a substantial role in the global C cycle and provide significant opportunities for climate change mitigation and adaptation. Currently, mangrove ecosystems worldwide are under substantial pressure from anthropogenic degradation, land use change, sea level rise and climate change. In Colombia, an extensive area of mangrove forests is harbored in the Magdalena River delta. The Magdalena River, one of the largest rivers in the world, has been the most important waterway in Colombia for centuries. The presence and development of the city of Barranquilla on the Magdalena River mouth, has heavily impacted the river and mangrove forests on its delta. Sediment supply and freshwater inflow of the delta have also been modified by land-use change in the catchment and the building of dikes. However, there is limited understanding of how mangroves in the Magdalena River delta and their C storage capacity respond to environmental changes, both natural and anthropogenic. We study mangrove forest development and C accumulation capacity using sediment cores from Cienaga de Mallorquin, a highly-degraded deltaic lagoon neighbouring the city of Barranquilla. Sedimentary sequences have been analyzed for their biological and geochemical signatures. The results suggest how ecosystem changes have influenced C sequestration rates over the last centuries and control contemporary C stocks in an environment heavily impacted by human activities.

Coastal sediments record mid-Holocene dynamics of sea level, extreme events, and the human societal response in eastern China

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Muddy coasts downdrift of large river mouths trap fine-grained sediments supplied from these rivers and have provided important settlement sites for prehistoric people, although the evolutionary history of such human-environment relationships has not been well described. In this overview of a number of well-dated sediment profiles and Neolithic sites from the northern and southern coasts of Hangzhou Bay, we deploy multiproxy evidence, including lithology, particle size, microfossils, organic and alkaline earth metal geochemistry, together with archaeological evidence, to reconstruct sea level changes and their associated societal impacts in the mid-Holocene. Neolithic occupation during ca. 8.0-4.0 ka occurred mainly during periods of stable sea level, while three major transgressions associated with sea-level rise interrupted the Neolithic cultures at ca. 7.6, 6.4, and 4.5 ka. Meanwhile, regional regression at ca. 5.6 ka favoured subsistence rice cultivation on the coastal plain. However, frequent storm events and saltwater intrusion at ca. 5.3-4.9 ka induced crop failure, possibly prompting the formation of a well-organized complex society i.e. the Liangzhu State theocracy. A further phase of sea-level rise at 4.5 ka, possibly in combination with climate change, triggered the collapse of the Liangzhu State, although a sea-salt industry emerged as an adaptive strategy of the coastal society in some localities. The integrated record casts light on the close linkage between environmental dynamics and the evolution of Neolithic cultures along the coast of eastern China.

Multi-centennial scale analysis of human-environment interactions in coastal areas: A multidisciplinary approach

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Coastal areas are dynamic and keep changing across time and space. Coastal changes are studied using proxies of thousands or millions of years old geological records, biological indicators, archaeological evidence, data from the tidal gauges (consistently available from 50-60 years), and satellite images. Most of these methods require elaborate field and lab facilities and provide data of a few point locations; therefore, do not represent the entire area precisely. Geospatial data provided by satellites covers a short span of time (i.e. past few decades). Considering the dearth of direct evidence in coastal research, the study of early cartographic records available from the 16th century onwards become a critical source of information to visualise the regional geomorphology of the time for which we do not have other direct evidence and inform us about the sequence of physical changes. There is no doubt that these geographical records, especially the earliest ones, contain errors and are inaccurate in many ways. However, this inadequacy can be overcome by applying a combination of a quasi-quantitative spatial approach and a quantitative geospatial model, which allows the integration of geographical data of heterogeneous nature. The present study demonstrates the invaluable contribution of historical coastal maps and maritime charts in expanding our understanding of long-term (300-400 years) coastal dynamics and their interaction with humans by applying multiple-perspective geospatial approaches to evaluate, validate and analyse the early maps. The suggested approach opens up the possibilities to harness the untapped potential that these maps have in the study of coastal geomorphology and maritime heritage.

Morphostructural evolution of the Granada rocky coast (Southern Spain) and its influence on urban areas: example from La Herradura section

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To support data acquisition and the field surveys, the use of remote sensing and GIS spatial analysis are necessary for coastal instability studies. In the Spanish Mediterranean coast, La Herradura section exhibits a clear example of the interrelation between geological structures and coastal landslides that affected populated areas. The coastal section of La Herradura is a 3 km-long bay constrained by two capes called Cerro Gordo (322 m altitude) and Punta La Mona (126 m elevation). The bedrock of both capes is part of the Alpujárride Complex, composed by Permian-Triassic marble, phyllite and schist, forming an Alpine S-vergent recumbent anticline affected by NW-SE and NE-SW normal faults since the middle Miocene. In this complex setting, the Cármenes del Mar and Marina del Este resorts were built just on the above-mentioned promontories, impacted by active slope movements almost since the beginning of the 21st century. Previous studies have already been conducted in these urbanised areas using photogrammetric and InSAR techniques, aimed at estimating the velocity of mass movements. Most are centimetres per year, but the displacements arrived at metric in specific sectors during highly rainy periods.

In our work, the analysis of the morphostructural framework revealed that the major tectonic structures have played a key role in the slope evolution of both study promontories, conditioning slope processes along faults, the bedding and tectonic foliations. First, by comparing the Cerro Gordo with the nearby Punta La Mona promontory, it was possible to give an assessment of the slope evolution of the promontories. In fact, both have similar lithology and geological structure, but they are morphologically different, due to an earlier evolution of the La Mona promontory. Second, the field survey supported by drone images and GIS spatial analyses have shown morphological features that suggest the existence of a large and ancient landslide in the eastern Cerro Gordo promontory. This implies that the active landslide affecting the Cármenes del Mar resort is only a nested body within a major mass movement involving the entire slope, entailing different implications regarding the interactions with the vulnerable elements therein.

Postglacial and Holocene environmental and sea-level change in northern Isle of Skye, western Scotland, and implications for human settlement.

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Edward Taylor, Natasha Barlow, Karen Hardy, Adam Booth, Graham Rush, Amy McGuire, Luis Rees-Hughes

Lithic artefacts found in the modern intertidal and coastal environments of northern Skye indicate Late Upper Palaeolithic human settlement in the area (Hardy et al., 2021) prior to and during the Younger Dryas ice advance that covered the Cuillin hills, thereby restricting migration from mainland Scotland and potentially creating a northern Skye refugium. Some artefacts have been found in amongst raised beach deposits, while others have evidence of rolling, suggesting they have possibly been reworked by tidal or wave action and redeposited. In some cases, these artefacts may have been transported from locations that are today underwater. However, sea-level constraints for this area of Skye are insubstantial which limits understanding of the environment occupied by this community.

We undertake analysis on a core, taken from a basin behind the raised beach in which the archaeological remains are found, to reconstruct changes in relative sea level, and palaeoenvironments, during the postglacial and Holocene in northern Skye. The basal bedrock topography was mapped through a Ground-Penetrating-Radar (GPR) survey and utilised to identify suitable sites for sediment coring. The stratigraphy is typified by marine clays at the base, followed by reed-rich clastic sediments, which are overlain by a sphagnum peat. By conducting diatom analysis, we identify the transition between saline, brackish and freshwater conditions, and ^{14}C date the timing of these changes in marine influence. Additionally, pollen analysis provides further evidence of local vegetation and climatic variability at the site. We hypothesise that, due to lower than present sea levels, Late Upper Palaeolithic people were able to occupy the previously exposed foreshore as well as the area nearer the basin. Sea level then rose through the early and mid-Holocene, subsequently blocking the marine basin by the formation of a mid-Holocene highstand cobble beach. This work provides an important context for these unique Palaeolithic settlements on the islands of western Scotland.

A landscape-scale geoarchaeological approach to long-term human-environment dynamics and heritage management in metropolitan Vancouver

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Metropolitan Vancouver in southwestern British Columbia, Canada, is situated along the coast of the Pacific Ocean, with a landscape characterized by rocky shorelines, large inlets, and the extensive Fraser River delta. Shoreline and nearshore environments are highly developed with residential, commercial, and industrial infrastructure, as well as large swathes of agricultural lands along the shores of the lower Fraser River. The region is also the traditional lands of multiple Central Coast Salish Indigenous Peoples and, despite the extensive development, it preserves a robust archaeological record documenting at minimum 9000 years of their cultural heritage. However, the landscape of metropolitan Vancouver that we know today is the result of Quaternary glaciations and a complex interplay of sea-level history, isostatic rebound, and the formation of the Fraser River delta following decay of the Cordilleran Ice Sheet (CIS) at the end of the Pleistocene. Ultimately, more than 300 km^2 of land emerged from beneath the sea during the Holocene due to the westward progradation of the Fraser River delta, and the archaeological record confirms that Coast Salish Peoples lived in the region alongside this immense reshaping and restructuring of the regional coastline. In this presentation, we draw on large datasets available through the BC Provincial Heritage Register and Canadian Archaeological Radiocarbon Database to integrate 9000 years of Indigenous occupation and use with the spatial and temporal patterns of landscape evolution to explore long-term human-environment dynamics in metropolitan Vancouver. We also demonstrate how a regional, landscape-focused approach to heritage management can provide evidence-based assessment tools within a highly urbanized context, helping to provide responsible solutions to address regulatory requirements and proponent obligations for project completion, while also balancing the interests of Indigenous communities and stakeholders, consistent with the principles and objectives of the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) and the UN Sustainable Development Goals.

Ultra-high resolution analysis of inter-annual natural and anthropogenic variability over the past 600 years documented by a prodeltaic depocenter in the Gulf of Cadiz (Spain)

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Due to low-resolution sediment deposition or discontinuous stratigraphy, investigating rapid environmental variability using sediment cores on continental shelves is challenging. Fine-grained fluvially sourced mud depocenters on continental shelves (MCDs), can provide an exceptional opportunity to examine such ultra-high resolution natural and anthropogenic processes. One such place to decipher the variability over the past centuries is the prodeltaic record of the Guadalquivir River in the eastern Gulf of Cadiz. This region is located between the Atlantic and Mediterranean climate systems and has a rich history of anthropogenic disturbances, particularly from the Industrial Revolution, affecting both the Guadalquivir River basin and regional coastal-marine system.

To analyze the timing and magnitude of changes and impacts, a 5-m long sediment core was taken at 23 m water depth from the Guadalquivir MDC spanning the past 645 ± 25 cal yrs CE. XRF core scanning at 1 cm resolution in conjunction with radiography imaging suggests three types of sedimentary facies within the core: hemipelagic (83%), flood event (15%), and storm layers (2%). High-resolution grain size, C/N isotope, and event-layer frequency analysis combined with elemental proxies and foraminifera assemblages are used to reconstruct climatic changes and environmental impacts on the river system, its estuarine mouth, and the offshore substrate during Little Ice Age to Anthropocene times.

Besides this classical approach, an ultra-high resolution preliminary study was performed on a flood layer using mass spectrometry imaging (MSI) *via* laser desorption ionization coupled to Fourier transform-ion cyclotron resonance-mass spectrometry for biomarker analysis along with micro-x-ray-fluorescence scanning (µXRF). Both MSI-based lipid biomarker analysis, targeting fluctuations of short- and long-chain fatty acids at 200-µm resolution, as well as 100-µm resolution elemental maps from µXRF measurements provide in-depth information on sediment source variations throughout a flood event.

Vegetation and arable farming in a Dutch Neolithic estuary landscape: first findings from the 'On Suitable Grounds' project in a wider context

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The interaction between people and the environment in the Early Neolithic in Dutch coastal wetlands has been studied extensively from the 1970's onwards. Settlements of the so-called Swifterbant Culture have been studied in detail, in particular those located in the polders of the present province of Flevoland, near the eponymous village of Swifterbant.
A recently started research project, 'Finding Suitable Grounds' studies the formation, age, and environmental properties of buried creek systems outside the polder area, buried under what is now the IJsselmeer. Using a combination of various geoarchaeologicaland palaeoecological proxies, we investigate the suitability for these landscape zones for early farming activities.
We will present the first findings from palaeoecological analyses on creek, levee, and floodplain deposits in this area, and place it in the context of the wider understanding of the interaction of the Swifterbant culture people with their environment. We will subsequently place this interaction in the broader discussion regarding arable farming in coastal wetlands in the Netherlands. This is a debate occurring in Neolithic, Bronze Age, and Iron Age research across the country. Finally, the degree to which this debate reflects the present perception of wetland landscapes, rather than past realities, will be discussed.

Shedding light on early embankments and associated landscape change on the Belgian coast using OSL profiling and dating

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Water management is a key element in the history of the Belgian coast. Nowadays, hundreds of kilometres of manmade dikes and channels characterise the region's landscape and contribute to its unique historical value. This is a fairly recent development. For most of its Holocene history, the coastal plain was an unembanked tidal marshland. Studying how it was transformed into today's manmade embanked and drained polder landscape is the main aim of TESTEREP, an interdisciplinary research project looking into the evolution of the Belgian Middle Coast over the past 5000 years (https://testerep-project.be).

The project is named after the Testerep peninsula, once located here between the cities of Nieuwpoort and Oostende. Testerep was separated from the mainland by a broad tidal gully, which was embanked and drained, and consequently ceased to exist sometime during the Middle Ages. A relative chronology for the embankment process in the Testerep region had already been established, but absolute dating evidence was largely lacking. To address this shortcoming, two case study areas were chosen for detailed investigation: one where a presumed late medieval embankment is still preserved aboveground, another where subsurface remains of a peat-reinforced bank, perhaps of Roman age, had been excavated 20 years ago.

In both cases OSL dating in the lab was combined with OSL profiling in the field using a portable OSL reader. This allowed luminescence-depth profiles to be constructed for both the banks and their underlying and overlying sediments. As a result, detailed chronologies could be created of when the banks were in use, but also of the landscape phases preceding and following them. The study helps us better understand the long-term evolution of the Belgian coastal plain and how people adapted to life in this dynamic environment, modifying the landscape itself in the process.

The sensitivity of a coastal environment as documented by the Late Holocene record from Lake Butrint (Albania)

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Lake Butrint (39°47 N, 20°1 E) is a coastal lagoon located in southwestern Albania along the Ionian Sea coast. Butrint is considered one of the most important Albanian archaeological sites with a considerable cultural, historical and natural value. It was declared a UNESCO World Heritage Site in 1992 and became a National Park in 2000. The lake's natural paleoarchive recovered as a 12 m long core composed of laminated sediments allows the high-resolution paleoenvironmental reconstruction of the last 4400 years. Permanent water stratification has led to the continuous deposition of varved sediments during the last millennia that, together with seven AMS radiocarbon dates and ^{137}Cs dating, contributed to the construction of a robust age depth model. The sedimentary succession has been widely investigated and sedimentological, geochemical, ostracod, dinocysts, pollen and microcharcoal data are available. These data document a coastal environment with marine influence that progressively became more terrestrial as evidenced by geochemical and ostracod patterns. Frequent earthquake shaking led to deposition of homogeneous turbidites that interrupt the laminated sedimentation. During the first part of the record in the Mid-Holocene, the present-day lagoon was a large embayment open to the sea. The progradation of the Pavllo River Delta caused the progressive isolation of the basin from the sea so that the Vivari Channel remained the only connection to the Ionian Sea since Roman times. Rather arid conditions occurred during warm periods such as the early Roman Warm Period (500 BC – 0AD), the Medieval Climate Anomaly (800-1400 AD) and after 19th century AD; fresher conditions occurred during cold intervals, i.e. the Late Roman-Early Middle Ages (0-800 AD) and LIA (1400-1800 AD). In summary, the Lake Butrint paleoenvironmental record is a combined result of climate variability, riverine processes, tectonic events and anthropogenic forcing, which all played together in shaping the region over the millennia.

Tracing a drowned medieval landscape –palaeoenvironmental reconstruction of the development of the Trendermarsch (North Frisia, Germany)

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The UNESCO Wadden Sea World Heritage Site in North Frisia is a coastal landscape characterized by intensive cultivation and land reclamation against the background of rising sea level and intense storm impacts throughout the late Holocene.

In the high to late Middle Ages, the Trendermarschkoog belonged to the island of Alt-Nordstrand, which was largely destroyed during a major storm surge (the 2nd Grote Mandränke) in 1634 AD. Parts of the cultivated marshland were, therefore, presumed to be seawards of the modern sea dike, hidden under the recent tidal flat sediments. On the land side, parts of this medieval marshland are preserved in today's Trendermarschkoog.

Reconstructing this sunken landscape requires a broad methodological spectrum. Geophysical prospections in combination with vibracoring provided insights into the subsurface of the Wadden Sea directly in front of the modern dike of Nordstrand. Moreover, sedimentary, geochemical and microfaunal paleoenvironmental parameters helped to identify the surface of the medieval landscape. Radiocarbon dating, archaeological age determination of ceramic fragments and historical reports and maps were used to establish a geochronological framework.

As parts of the preserved medieval Trendermarsch, we identified dikes, ditches, dwelling mounds (terps) and cisterns and their individual signatures in the sedimentary record of the Wadden Sea. Moreover, we were able to reconstruct the palaeogeography of wide parts of the medieval Trendermarsch, partly drowned in the present-day North Sea. Finally, our findings provide a reliable basis for further (geo-)archaeological investigations in offshore near-coast areas of North Frisia.

Session 160: Geoheritage: role of scientists to keep earth scientific treasures for future generations

Quaternary Science-Based Geoheritage Evaluation: Constructing Effective Criteria for Arid Environments

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Since the establishment of the UNESCO Global Geoparks program in 2015, geoheritage conservation has developed considerably. An emerging issue amidst this rapid expansion is the geographical and typological imbalance of protected sites.

Quaternary geoheritage sites in arid environments, such as the Middle East and North Africa (MENA) region, form an under-protected type of geoheritage. These sites are important not only to understand the development of the regional landscape and for geohazard management, but also to understand the relationship between past climate change and human settlement/migration. Nevertheless, they remain largely unprotected, despite reports of their destruction from regions such as Southeast Arabia.

To protect these sites, robust criteria for their evaluation are essential. Although many methods have been proposed, evaluation of the scientific values of geoheritage sites has largely relied on the expert knowledge of a few researchers, without input from the broader scientific community. Moreover, there is geographical imbalance in expert opinions, which are largely based on European experience. Only a few studies have targeted arid environments or Quaternary geological/geomorphological sites.

Challenging this *status quo*, the present study created a new method to evaluate scientific values of Quaternary geoheritage sites in arid environments based on a survey of 43 interdisciplinary researchers (i.e. geoscientists, archaeologists, and evolutionary anthropologists) with interests in arid environments. The survey asked participants to assess the relative importance of 11 factors related to Quaternary sites and to rate the appropriateness of the types of proxies used to evaluate each factor.

Compared to previous studies, this method appoints a higher weighting to rarity, scientific knowledge, and archaeological relevance, and a lower weighting to site integrity and geological diversity. The importance of the archaeological connection is especially noteworthy, as it provides support for a “geocultural” approach to protecting Quaternary geoheritage sites in arid regions. Overall, this project demonstrates the necessity of involving the geosciences community to create environment- and type-specific criteria to identify scientifically valuable geoheritage sites.

Geoheritage and geoconservation in the sub-Antarctic: An illustration from the Prince Edward Islands from a South African perspective

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The Prince Edward Islands (Marion Island and Prince Edward Island) are the only South African territories in the sub-Antarctic and an important platform for South African led terrestrial science in the greater Southern Ocean. Using high-resolution satellite imagery and digital elevation data, more spatially accurate information of the surface geology of the Prince Edward Islands were recently presented. The islands enjoy the highest level of protection afforded to any natural area under South African law and are managed under the Prince Edward Islands Management Plan (PEIMP). Conservation efforts on the Prince Edward Islands have focussed on the protection of biological species, preservation of archeological artefacts, the management of pollution and waste and preventing the further introductions of alien species, but the conservation of geodiversity has received limited attention. This presentation shows how a standard geological and geomorphological mapping and ground surveying exercise was used to 1) highlight that certain geological features and specimen from the Prince Edward Islands are unique examples of geodiversity in a South African context; and 2) recommend a more comprehensive geoconservation strategy be incorporated into the PEIMP. Geological features that should be regarded as important elements of geodiversity include large landforms as well as removable specimens. For large feature such as lava tunnels, tubes and the modern-day lava flows and ash cones, we present the scientific reasoning and recommendations for a higher conservation designation to protect their structure. Whereas removable specimens such as pyroxene megacrysts and lava bombs associated with Pyroxene Kop on Marion Island and Kent Crater on Prince Edward Island, should be protected with more prescriptive collection restrictions. The Prince Edward Islands may not necessarily present international value in terms of UNESCO geoheritage standards, but they certainly contain geological features and specimens that are scientifically valuable and rare elements of geodiversity in a South African context and should be included in future assessments and policy of South Africa's geoheritage.

Geoheritage and Geological Mapping in Ireland

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1. *Geological Survey Ireland*

The Geological Heritage programme of the Geological Survey Ireland (GSI) works to protect and promote the appreciation of geological heritage sites of national and international importance in Ireland. Ireland is well represented by its number of audited county geological heritage sites (CGS) that make up a national inventory of over 900 CGS which is likely to be completed by end of 2024. Furthermore, Ireland has three UNESCO Global Geoparks (UGGp) and one aspiring UGGp. This is a reflection of Ireland's rich geodiversity.

Despite CGS having no statutory protection in Ireland many counties have adopted CGS into their County Development Plans and also promote their public interest and preservation through Heritage Plans. This recognition, and de facto protection, of the national inventory of CGS is an appreciation of the significant contribution geological heritage makes to; our knowledge and understanding of past climate changes; documenting geodiversity which is linked to biodiversity and; our cultural heritage, tourism and education sectors.

The Irish landscape is dominated by glacial features of Quaternary age and correspondingly, almost half of Irish CGS have a direct link to themes associated with the Quaternary Period. Many other CGS have Quaternary features of note that are listed as part of the management and promotion strategy for these sites.

The Geological Mapping Programme in GSI supports the Geological Heritage programme by updating maps that depict the rocks and Quaternary deposits of the onshore area of Ireland. Quaternary geological mapping activities focus on areas of low confidence in the national Quaternary Sediments and Quaternary Geomorphology maps where stakeholder interest is high. CGS are always an important target for data acquisition when mapping an area as these sites often have a strong history of research activity. The synthesise of this existing research for the site often permits an updated understanding and an assessment of site specific preservation risks and allows the geologist to gather further information to deepen the store of knowledge of these sites.

Microbial and chemical characterisation from occupation contexts involved in the preservation of Roman writing tablets.

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Soil at the Roman site of Vindolanda (Northumberland, UK) provides excellent preservation of wooden artefacts including Roman writing tablets containing what is thought to be the oldest example of a women's handwriting. In this study we examined how chemical and microbial signatures change within varied occupation contexts of archaeological soil. Analysis included investigating elemental composition, bacterial diversity and community structure from excavation trenches at Vindolanda using pXRF and 16S rRNA gene amplicon sequencing. Samples were taken from varying depths starting at topsoil and working down through layers of Roman occupation including one cavalry stable floor, two infantry barracks and a cook house and layers which contained Roman writing tablets.

The chemical results indicate that areas where wooden artefacts were found had increased soil moisture which was also correlated with specific chemical conditions including shifts in iron, sulphur and phosphorous concentration. Sterols decomposing plant material were detectable from preservation layers only.

Microbial diversity was not correlated with depth but differed due to soil moisture and carbon availability. Overall microbial community structure was influenced by soil type (anaerobic, aerobic or waterlogged) and occupation context with layers showing best preservation of artefacts having different microbial communities to those without. Microbial community structure and putative function, as inferred by PICRUSt2, is linked to occupation usage rather than depth of samples with laminated floor layers differing from turf structures.

Understanding the complex processes within archaeological soil can help us to understand dynamics of decomposition and preservation. In addition, the apparent preservation of the environmental microbial community as well as the artefacts themselves allows expansion of this work allowing us to understand the microbial environments of the past, how they relate to the present and what this means for our changing environments in the future.

In this presentation we will show our data from the Vindolanda site and talk of our planned expansion of the work to cover the unexcavated peatlands found at the Roman site of Magna.

Applications of the Microbially Induced Calcium Carbonate Precipitation.

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Microbial-induced calcium carbonate precipitation (MICCP) is a naturally occurring biological process in which bacteria promote the production of calcium carbonate, from microscopic crystals to large geological formations. This technology has been extensively explored in various environmentally friendly applications, such as the biorestoration of limestone monuments and can help to reduce the consequences of climate change through atmospheric fixation of CO_2, the main contributor of greenhouse gases. Thus, the application of this technology can counteract the ever-increasing concentration of CO_2 in the atmosphere and the extreme acceleration of the degradation of stone artworks due to global warming and increasing environmental pollution. However, while biomineralization is a common phenomenon among bacteria, not all microbes are suitable for such an application, due to their slow growth rate and low conversion efficiency and because many of them not only precipitate but also dissolve calcium carbonate. Consequently, we characterized a collection of bacteria isolated from several Cultural Heritage artworks, mainly from limestone highly degraded by atmospheric factors. We selected the most suitable bacterial strains by analyzing their ability to precipitate calcium carbonate crystals, studying the amount of precipitation in different media and conditions. In fact, biomineralized carbonate can also be useful in a wide range of applications such as sand consolidation, filling of pores and cracks by reducing water permeability in concrete, cement mortar restoration, increased strength of bricks. Our work is focused on carbonatogenic bacteria isolated from artworks to establish a *workflow* for *in situ* biorestoration applied on different calcareous materials, such as mortars and different limestones. This process involves the formation of crystals of calcium carbonate and has the potential to store large quantities of CO_2 and can be applied in different context using the MICCP for several applications, seeking also to counteract climate change effects.

Climate change and cultural heritage: a unique and fragile interaction

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Archaeological sites and hypogeal tombs are considered the most exposed cultural heritage sites to climate changes. For thousands of years, these sites were preserved in specific, and sometimes extreme, natural environments, with which they have established a perfect equilibrium. The slightest variation of one of the environmental parameters could irreversibly modify the conservation of these archaeological sites. For example, in the hypogeal Etruscan tombs of Tarquinia, even a slightly variation of temperature and/or humidity could lead to the activation of microbial proliferation, irreversibly altering the mural paintings. In the Phoenician archaeological site of Mozia, the modelling of climate changes has predicted future floods, thus, a dramatic changes in salt content experienced by the microbial communities could accelerate the biodeterioration. There is a need to raise awareness, to draw up a future action plan to contain the damage caused by climate change at the most at-risk sites. The aims of this work are the following: firstly, to study the microbial community and its interaction with the different substrates in these sites of great historical and cultural interest, using molecular and analytical techniques to characterise the metabolic products of microorganisms. Then, changes in environmental parameters will be simulated in laboratory to assess the resilience of the microbial community to specific modifications, to design an action plan that could be applied in the future, if necessary. Finally, in line with the guidelines to reduce the impact on the environment, more sustainable alternatives for the removal of biological patina will be tested.

Session 162: Astronomical forcing and nonlinear climate feedbacks during the Pleistocene Epoch

Freshwater release from under an Arctic ice shelf triggering rapid climate oscillations

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At the seafloor of the Arctic Ocean and the Nordic Seas, traces of erosion by ice can be found down to surprising depths. For the Central Arctic Ocean, almost 1000 m are confirmed; in Fram Strait, which connects the Arctic Ocean to the Nordic Seas, up to 1200 m; south of Jan Mayen in the Nordic Seas at 850 m; and around the Greenland-Scotland Ridge, which connects the Nordic Seas to the North Atlantic with a depth of max. 900 m today, around 940 m below current sea-level. This ice thickness is best explained by extended ice shelves, which is also supported by model calculations. The observed differences in shelf ice thickness would have created under-ice cavities that can trap freshwater.
In periods of sea-level low stands, the outflow from the Arctic Ocean to the Pacific was blocked by land (Beringia), while rivers from East Siberia were still discharging freshwater into the shelf-ice covered Arctic Ocean- in addition to the freshwater input via glaciers. The combination of restricted outlets for freshwater from the entire Arctic drainage area, under-ice cavities due to different ice thickness in the basin, and a strong variability of local seafloor depths due to glacial erosion, isostatic change, and sea-level rise offer a mechanism to explain rapid climate oscillations.

A sudden release of freshwater from under the ice shelf must be accompanied by the penetration of large volumes of relatively warm, salty water into the Nordic Seas or the Arctic Ocean, leading to strong amplification of minor changes in sea-level, bathymetry or insolation by sudden heat transfer. This scenario is not only plausible when combining the available evidence, but it is also supported by strong proxy evidence. However, it also conflicts with several existing interpretations of Arctic and North Atlantic marine sediment records. This conflict has sparked considerable debate. Here, we give an overview of the state of the discussion and present more data in support of a temporary under-ice freshwater system in the Arctic Ocean and the Nordic Seas.

Meltwater-AMOC feedbacks at the centennial to millennial scale from speleothem records

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It has been difficult to empirically evaluate if meltwater was the trigger of most AMOC reductions during stadial events, or conversely if meltwater release was the consequence of subsurface warming and marine ice sheet destabilization during stadials? The decadal scale resolution of speleothem records provides a unique perspective on the leads and lags between freshening and cooling at the onset of D-O type events. The Northwest Iberian Speleothem Archive (NISA) from coastal caves is ideally situated since it records both meltwater events which decrease the d18O of the eastern North Atlantic ocean, as well as regional coolings resulting from AMOC reductions (via speleothem d13C). We present new perspectives on the interplay of meltwater and abrupt coolings during diverse periods of the last two glacial cycles, including MIS 5a, Termination II, and millennial variations within MIS 6. Over TII, freshwater forcing initiates AMOC weakenings early in the termination, and the short duration of the first AMOC reduction is consistent with a negative feedback between AMOC cooling and melt rate. In contrast, early in MIS 6, we find abrupt coolings which preceed by a century evidence for freshening. Such records should provide important constraints on model explorations of the sensitivity of AMOC to disruption under different boundary conditions.

Multiple mechanisms responsible for deep Atlantic oxygenation variations during MIS 4 with implications for oceanic respired carbon storage and atmospheric CO2

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The deep ocean likely played a key role in modulating atmospheric CO_2 on millennial and astronomical timescales, through respired carbon inventory changes. Because the amount of seawater Corg broadly scales with the $[O_2]$ via Redfield ratio, we apply bottom water O_2 ($[O_2]_{bw}$) reconstructions to elucidate the oceanic mechanisms of CO_2 variability during MIS 4. MIS 4 is a key paleoclimatic interval of the last glacial inception, characterized by a rapid CO_2 drop of ~40 ppmv, and includes several millennial events, eg. Heinrich Stadial 6.
Here, we present multi-proxy $[O_2]_{bw}$ reconstructions from an Atlantic depth transect spanning the Iberian Margin to the sub-Antarctic South Atlantic, using redox-sensitive foraminiferal U/Ca and $\Delta d^{13}C$ between pore and bottom, supported by qualitative inferences from benthic foraminifer assemblages. We interpret the $[O_2]_{bw}$of a deep water mass as determined by: the amount of O_2 consumption (through respiration), and the amount of O_2 supply (influenced by concentrations at the sinking region(s), and ventilation changes).
Whilst the mid-depth North Atlantic (~2.6km) shows gradually decreasing $[O2]_{bw}$ into MIS 4, a minimum during HS 6, and subsequent recovery at the onset of MIS 3; in the abyssal North Atlantic (~4.6km), the U/Ca record maintains relatively constant and high $[O2]_{bw}$ throughout, supported by benthic foraminifera assemblages. The South Atlantic (~3.8km) differs from both: rapid reduction in $[O2]_{bw}$ into MIS 4 followed by clear increase during HS 6, reminiscent of the Antarctic CO_2 records. Our reconstructions suggest an accumulation of respired carbon in both the mid-depth and deep (~2-4km) North and South Atlantic Oceans at the onset of MIS 4, lowering atmospheric CO_2. However, during HS 6 continued North Atlantic $[O2]_{bw}$ draw-down and a large carbon release from the South Atlantic suggest significant ventilation impacts on oceanic respired carbon storage, mediated through the bipolar seesaw. Proxy records from abyssal depths are probably controlled by extremely low C_{org} (export) fluxes, preventing oxygen consumption.
Thus, our results highlight the differences between mechanisms of deep-water oxygen supply, versus oxygen consumption (ultimately local C_{org} and global atmospheric CO_2 variability), underlining the difficulty of disentangling their contributions to U and/or $d^{13}C$ cycling, on millennial versus orbital timescales.

An 800’000-year-old tag game: high-res viewpoints on CO2-Antarctic temperature phasing under different orbital frames

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Many novel atmospheric CO2 ice-core records have appeared since the last 800-thousand-year (800 ka) compilation in 2015, with several-fold improvements in resolution. Similarly, water isotope-based ice core reconstructions have also improved, allowing more precise phase studies between CO2 and Antarctic site and source temperatures. Alongside these developments, new well-constrained age scales have also spawned, reducing lead-lag uncertainties to sub-millennial scales. Here we draw from the most up-to-date ice-core datasets within the last 800 ka and study the phasing and rate evolution between CO2 and different Antarctic temperature reconstructions, in particular during glacial terminations and glacial inceptions. Our results evidence an overall pattern linking different CO2-Antarctic temperature pathways to specific orbital configurations, explaining some of the interglacial variability. Further, we propose that glacial inceptions may be induced via an obliquity threshold, after which cooling in Antarctica sets in. The timing between this cooling and the moment atmospheric CO2 concentrations fall toward glacial values can be to first order attributed to purely orbital features. In particular, the time elapsed between reaching the obliquity threshold and the next minimum in Northern Hemisphere Summer insolation seems to regulate any ensuing lag between CO2 and Antarctic temperature. Using a novel high-resolution atmospheric CO2 dataset covering the last interglacial (135–105 ka), we mechanistically ascribe the observed sharp CO2 drawdowns during glacial inceptions to abrupt weakening events of the Atlantic Meridional Overturning Circulation. We further suggest that these fast transitions were possibly triggered by a series of cascading events in the Northern Hemisphere that ultimately lead to the establishment of a deep ocean CO2 reservoir.

What do paleothermometers tell us about the mid-Pleistocene transition? The combination of Mg/Ca, clumped (Δ47) and conventional (18O) stable isotope in planktonic foraminifera

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The Mid-Pleistocene transition (MPT - 1,2 Ma to 0.8 ka) allowed the establishment of the Late Pleistocene climate with the 100 ky orbital cycles. The orbital variations alone cannot explain the shifts in climatic periodicity of the MPT. The evolution of internal mechanisms and feedbacks have been called upon, in relation with the global cooling trend, the expansion of Ice Sheet and/or the decline in [CO_2]atm. A key point is therefore to accurately reconstruction of oceanic temperatures (SST) and to decipher the processes driving climate variations.

Here, we studied the marine sediment core MD96-2048 taken from south Indian Ocean in the source region of the Agulhas current. We compared 5 thermometers: alkenone, TEX86, foraminiferal transfer function (TF), Mg/Ca and clumped isotope (Δ_{47}). All thermometers have been measured at high resolution, except for Δ_{47} that focuses on the maximum of glacial (G) and interglacial (IG) periods over the last 1.2 Ma. Strong differences are observed between the 5 derived-SST: the alkenone and TEX86 recorded higher temperatures than the other proxies. Alkenone-SST do not show G-IG variations within the MPT. The Mg/Ca- and the TF-SST show a good agreement to each other, while the Δ_{47}-SST are systematically colder than the other SST proxies.

The $d^{18}O$ is dependent on SST and $d^{18}Osw$, which is regionally correlated with the salinity (SSS) in the present-day ocean. The Mg/Ca is controlled by SST and affected by SSS and pH, while the Δ_{47} is only SST-dependant. If the present-day $d^{18}O_{sw}$-SSS relation was the same during the MPT, we can separate changes in $d^{18}O_{sw}$ from SST effects and reconstruct past SSS. The $d^{18}O$, Mg/Ca and Δ_{47} combination may then allow the reconstruction of SST, SSS and pH. We used this new approach to estimate the long-term evolution of past SST, SSS and pH across the MPT. The SST (excepted for Δ_{47}), SSS and pH results show that amplitude of G-IG variations was insignificant between 1.2 and 0.8 Ma and increased after the MPT.

Nonlinear response to insolation in a context of low CO2 for triggering the onset of Greenland ice sheet during Pliocene/Pleistocene boundary

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The Plio-Pleistocene boundary, a milestone between Pliocene warm climate and cooler Quaternary is an important tipping point in the recent evolution of the climate at geologic time scale. From a largely asymmetric planet, with predominantly, one ice sheet located over the polar region of the Southern Hemisphere, and associated deep-water formation, the climate shifted to a more bipolar system.

To explore this large climatic change, it is necessary to investigate a long period (3-2.5 Ma), using climate and ice sheet models. The driver of such a transition has long been pointed out as the astronomical forcing with a large insolation decrease around 2.7 Ma, in a context of low CO_2 compared to Miocene values. However, no real transient experiment using an atmosphere ocean general circulation model (AOGCM) was able to prove this. To explore this issue, we developed a dedicated coupling between AOGCM and ice sheet model (ISM), based on a mapping of the phase space. Therefore, we constructed a tri-dimensional matrix based on 3 driving parameters: atmospheric CO_2, insolation and different configurations of Greenland ice sheet (GRIS), ranging from no ice sheet to an equivalent pre-industrial (PI) GRIS. Specifically, we used two values of insolation (maximum and minimum summer insolation occurring at 65°N for this period), four pCO_2 values spanning the reconstructions: 220, 280, 360 and 405 ppm, and seven GRIS configurations. In total, we performed 56 snapshot climate simulations.

Once the "mapping" is available, this allows us to quantify the threshold of pCO_2 necessary to trigger the GRIS, using variations of summer insolation at 65°N, and demonstrate that it has to overcome a threshold between 280 and 320 ppm. More interestingly, this method enables us to compute the GRIS evolution, using different sets of pCO_2 reconstructions for the period 3.0-2.5 Ma, accounting for insolation changes. We may compare our simulations to sea-surface temperature (SST) and ice rafted debris (IRDs) available for that period over Greenland and to diagnose which pCO_2 reconstructions is the most appropriate.

In summary, this approach demonstrates the nonlinear response of the cryosphere and climate system to orbital forcing when pCO2 reaches values around 300ppm.

Prospects of suborbital astronomical tuning in the field of geochronological and climate change research

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Accurate geological time is the key to reveal the Earth's evolutionary history and geological processes. Astronomical theory based on the paleoclimate changes has been successfully applied to the calibration of geology time scale. However, astronomical solution in suborbital scale has not been established due to the relatively poor understanding of the astronomical cycles and the driving mechanisms of climate change in suborbital scale. In this study, we set up a suborbital-scale climate database from published climate indicators of ice cores, stalagmites, tree rings and lake sediments. By spectral analysis, cross spectrum of wavelet transforms and amplitude modulation, we find that different deposition archives show strong and stable suborbital cycles about 500, 1000 and 2000 years. These cycle signals are significantly correlated with the interannual-millennial scale cycle of solar activity and may be the amplitude-modulated cycles of 11, ~88 and ~210 years solar activity cycle. This amplitude modulation relationship is similar to the eccentricity modulated precession cycle in orbital scale. This illustrates that the century and millennium cycles show a great potential for suborbital-scale chronological tuning, especially the 500-year cycles. In this study, we applied a stable 500-year solar activity cycle to build an age model for the stalagmite record in Dongge cave and surface eolian sediments record in northern Qilian Mountains. The results show that the duration derived by our suborbital astronomical tuning method is consistent with the high-precision U-Th dating results in stalagmite deposition and radiocarbon dating in eolian sediments. The difference is only 50 years in stalagmite and 100 years in eolian sediments. The successful use of suborbital cycle calibration the geological time scale demonstrates the operability and practical value of this dating method. Our results reveal the relationship between solar activity and Earth's climate change, which has a good application prospect in chronology research. This study helps to advance the study of Earth's climate evolution at suborbital scales, and also has important implications for predicting future climate change on short time scales that are closely related to human development.

Session 163: Quaternary palaeoenvironmental dynamics/variability: promoting multiple proxy records from West-Central Africa

Holocene vegetation and climatic changes in coastal tropical rainforests

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The Holocene vegetation and climatic history of the tropical rainforest (TRF) in coastal south-western Nigeria was investigated through the palynological study of sediment cores retrieved from four coastal localities, namely Ahanve, Ogudu, Otolu-Lekki and Ikorigho. In Ahanve and Ogudu, during the middle Holocene the TRF, comprising lowland rainforest (LRF), mangrove swamp forest (MSF) and freshwater swamp forest (FWSF), was abundant and extensive, indicative of the prevalence of a wet climate and high sea levels. In the late Holocene, with the onset of drier climatic conditions, there was a westward decline in the TRF along with a steady increase in charcoal particles. The LRF and MSF decreased significantly and the MSF eventually disappeared by 1440-1310 cal. yr BC (3109 ±26 BP) in Ahanve. The MSF and LRF were replaced by coastal savannas and secondary forests, respectively; there is archaeological evidence of the presence of humans and their impact on the environment in the area at this time. In Ogudu, the TRF also declined drastically at 2760-2730 cal. yr BP (2620 ± 30BP); it recovered subsequently but did not attain the previous level of diversity. In Ikorigho, the TRF declined at 1240-1200 cal. yr BP (1210 ±30 BP); it too recovered and diversified subsequently. At Otolu-Lekki, although still substantially diverse, the LRF and MSF experienced slight decreases which were accompanied by marked increases in charcoal particles and the appearance of the pollen grains of several exotic plants from Asia and South America. The palynological and anthracological evidence has shown that the decline of the TRF in the area during the middle and early late Holocene was initially climate driven while subsequent and recent decline has been exacerbated by anthropogenic factors.
Keywords: Tropical rainforest, palaeoenvironment, Holocene, human impact, coastal southwestern Nigeria

The diatomic lacustrine deposits in the Hassi Mouina of the Grand Erg Occidental, North Western Algerian Sahara, during the lower and middle Holocene

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One of the interdune depressions of the Grand Erg occidental with lacustrine sedimentation in the region of Hassi Mouina was the subject of a diatomic study.This paleolake is in the form of a control mound metric thick (3m maximum) and made up from bottom to top: blackish clays (5 cm) topped with diatomic limestone. The whole rests on fine yellowish sands.
The set of diatomic limestone shows two very distinct parts according to the presence of traces of plants which mark their appearance from the 9th level to the top.
The analysis of the diatomic microflora provided a total of 19 genera (18 pennal genera and a single centric genus) belonging to two ecological groups according to the way of life (habitat). The most dominant littoral taxa (epiphytic and epilithic) are: *Epithemia* Brébisson ex Kûtzing, 1838, *Mastogloia* Thwaites, 1856, *Nitzschia* Hassall, 1845, *Cymbella* Agardh, 1830, *Gomphonema* Ehrenberg, 1834, while the planktonic forms are not represented by *Cyclotella* Kutzing, 1834.
The quantitative and qualitative distribution of microflora makes it possible to distinguish 10 zones representing periods of water level change.
The paleoenvironmental analysis of these 10 identified zones makes it possible to identify three phases of sedimentation:
- a phase characterized by a shallow, mixed environment (freshwater-oligosaline water); strongly alkaline.
- a phase characterized by unstable hydrological conditions with rapid fluctuations in the level of the water body which reflects a very shallow environment, fresh water with a tendency towards olig-meso-polysaline waters, attested by the high frequencies of the taxon *Mastogloia smithii*.
- one phase bears witness to a slice of very alkaline shallow water, attested by the low frequencies of epiphytic taxa reflecting a mixed environment (olig-meso-polysaline water to fresh water).
Keywords: Grand Erg Occidental, Hassi Mouina, sedimentation, lacustrine, Holocene, diatoms, Paleoenvironment.

Palynological evidence for the rapid disappearance of Mangroves around the Lagos coastal environment (LCE) in the late Holocene

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Coastal environments are regarded among the most threatened habitats in the world, often associated with anthropogenic activities whose impact range from ecosystem alteration to biodiversity and socio-economic loss. A multi-site palynological and sedimentology study of 60cm sediment cores from five locations a Universal peat corer from the coastal environment of Lagos, Southwestern Nigeria was conducted. These were subjected to standard palynological procedures, as well as lithological, pH and salinity analysis. Recovered and identified species of Mangroves *were* found to be disappearing in all the study sites. Also recovered were taxa from freshwater swamps, lowland rainforest, marine/freshwater, open coastal forest/savanna and fungal spores. The preponderance of mangrove, freshwater swamp and lowland rainforest species is suggestive of a generally humid climate. However, there were periods of dry climate indicated by open/secondary forests or savanna. Absolute AMS dates showed the sequence was deposited around the last 1480±30 BP. Furthermore, a series of lithological types were recognized suggesting overbank or floodplain settings of a low-energy regime. The pH and salinity values varied considerably across the cored depths and locations while the lithological analysis revealed a mosaic of sedimentary depositional environments in which the recovered palynomorphs were preserved. This multi-site palynological analysis across ecosystems revealed that the last 1480 yrs BP witnessed significant vegetation changes occurring in this area, transiting from a more mangrove and lowland rainforest vegetation to an open/secondary or savanna setting compounded by anthropogenically driven disturbances. It provides the first record of the rapid disappearance of mangroves in the late Holocene from the region.

Keywords: Coastal Environment, Past Vegetation, Sediments, Palynomorphs, Late Holocene, Nigeria

A Late Quaternary Pollen, Vegetation and Climate record from Coastal deposits, Southwestern Nigeria.

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Palynological and sedimentological studies were carried out on sixteen borehole samples drilled within the Benin Formation of the Benin Basin in Ota, Ogun State of Nigeria. This study was aimed at investigating the pollen records from the basin leading to perspectives on the vegetation and climate history with time. From the predominantly coastal plain sandy lithofacies, significant pollen such as those of *Rhizophora* spp., Poaceae, Cyperaceae, Amaranthaceae and *Elaeis guineensis* as well as freshwater pteridophytes spores with diverse fungal spores were recorded. Significant proportion of charred Poaceae cuticles were also recorded. The pollen vegetation indicated humid tropical conditions prevailing at deposition. The well established less representation of *Rhizophora* spp. and the sharp rise in the pollen of *E. guineensis* associated with the Late Quaternary suggested age in the range between ca 3000 yr. BP and ca. 2000 yr. BP.

Two pollen zones, a dry Pollen Zone I, typified by low records of freshwater swamp forest, lowland rainforest species with high Poaceae pollen and CPC, and a succeeding wet Pollen Zone II, associated with increase in wet climate floral components with reduction in dry climate elements, were recognized. The two zones were associated with the West African climates post-Noukchottian transgression of the Tafolian regression (4000-2000 yr. BP) and its succeeding Sea Transgression recorded between 2000-1700 yr. BP. This study depicts a typical humid tropical forest in climatic conditions alternating from a dry to a wet phase. Evidence of anthropogenic farming activities was inferred from the trends in the records of *E. guineensis* and charred Poaceae cuticles.

Keywords: Benin Formation, Benin Basin, Noukchottian transgression, Tafolian regression, Ogun State.

Word Count: 255

Reconstitution and forward 3D numerical modeling of a marine paleoenvironment: case of Quaternary formations in Northern Morocco

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A model for reconstructing a sedimentary basin can be developed using sedimentological and micropaleontological analyses. Geomodelling can simultaneously represent the subsurface's geological structures and the geometry and properties of these geological formations. The example chosen in this work is the Pleistocene marine formations in the Achakkar area in the West of Tangier-Morocco. In this study we propose a new approach to reconstruct the history of the implementation of these formations based on sedimentological, micropaleontological analyses and to integrate these data, for the first time, in a mathematical model. These model allows a 3D distribution of sedimentary facies using Cellular Automata. Sedimentary modelling consists of predicting the architecture of sedimentary forms and the distribution of their facies.
Keywords: Quaternary of Morocco, Sedimentology, Micropaleontology, Geomodelling, Cellular Automata.

Session 164: Understanding MIS 5d-a: sediments, paleoclimate, chronology and long distance correlation

Land - sea correlation of late MIS5 deposits in the southern North Sea region

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During the Weichselian Early Glacial (MIS5d-a), rapid climatic changes occurred where global sea level varied tens of meters between the stadial (MIS 5d,b) and interstadial (MIS5c,a) periods. This was followed by a major sea level drop into the Early Pleniglacial (MIS4). Shallow, low-gradient shelf sea regions were significantly impacted by these shifts in sea level and the associated temperature variations, resulting in shifts in coastline configurations and changes in the vegetation characteristics of the surrounding landscapes.
The southern North Sea is an example of such a shallow shelf sea area, but the effects of Early Glacial climatic variations are poorly understood. Here, clay-rich Early Glacial sediments, referred to as the Brown Bank Formation (also known as Brown Bank Member), are known to occur in a vast region with a thickness varying between 2 and 20 m. In studies across the southern North Sea, shallow marine, lagoonal and lacustrine deposits have been described for the Brown Bank Formation, with ages linked to the period from MIS5d to MIS3. For this study, the Brown Bank sediment has been studied in unprecedented detail at its type area. Analyses of core material show shallow marine to pro-deltaic sediments deposited during the final phase of MIS5a and the transition into MIS4.
In order to place these sediments into a context of regional climatic, landscape and sea-level changes, and to better understand the sediment supply systems and processes, a solid land-sea correlation is needed. To achieve this, data from the Brown Bank Fm are compared with Early Glacial (i) deposits found onshore in the Saalian glacial Amersfoort basin and (ii) sediments cored offshore the Maasvlakte. Such long-distance correlations have been possible by combining core data with high-resolution seismic data. We will focus specifically on the comparisons of Early Weichselian deposits from these three locations by discussing the lithology, age and palaeo-environmental indicators. This will enable us to understand the evolution of this depositional systems in response to climatic changes during Late MIS5 and the MIS5-MIS4 transition in the North Sea basin.

Constraining MIS 5a and 5c highstand ages: New dates and stratigraphy from the Florida Keys Reef Tract

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Marine Isotope Stage (MIS) 5a and 5c represent sea-level highstands before the most recent marine regression and are useful records for building linkages between sea-level fluctuations, orbital forcing, and ice-sheet dynamics. However, Global Mean Sea Level (GMSL) estimates for these sub-stages, occurring after the well-constrained MIS 5e, contain meters of uncertainty and fewer data points due to several challenges. In the Western Atlantic, MIS 5a and 5c shoreline facies are mostly eroded or not deposited, while dateable in-situ coral facies in tectonically stable regions are submerged by MIS 1 sea level. More robust MIS 5a and 5c data with absolute age constraints and well-defined indicative ranges are needed to infer GMSL and correct for Glacio-Isostatic Adjustment and long-term deformation.

Twenty three cores from five sectors of Florida Keys Reef Tract (FKRT) taken by the United States Geological Survey were logged. Across the Dry Tortugas, Lower Keys, Middle Keys, Upper Keys, and Biscayne subregions, 34 coral samples were taken from below the Holocene-Pleistocene contact bounded by previously radiocarbon-dated Holocene-age corals. After passing XRD screening (≤2.7 % calcite), U-Th concentrations were measured by a Multi-Collector Inductively Coupled Plasma Mass Spectrometer (MC-ICP-MS) using a ThermoScientific NEPTUNE PLUS ICP-MS in the Department of Earth and Planetary Sciences at Rutgers University. U-Th dates generated for 20 coral samples, including *Pseudodiploria strigosa, Siderastraea siderea, Acropora palmata, Orbicella* spp., and *Porites astreoides*, yielded MIS 5a ages and 3 coral samples, consisting of *Pseudodiploria clivosa,* and *Orbicella,* yielded MIS 5c ages. Corals dated to 5a ages were 6.13-19.18 meters below present (uncorrected) sea level. *Acropora palmata* framework in the Lower Keys was found 12.6 m below present at 83,941 ± 143 years (2σ) and interpreted to represent 5a reef crest facies. The recorded depths will be cross-referenced with modern coral depth distributions to generate sea-level estimates within each time-step for 5a and 5c. Despite containing shorter transgressive intervals than 5e or the Holocene, MIS 5a and 5c-aged reef deposits exist extensively along the FKRT, suggesting larger coverage than in previously dated deeper outlier reefs of South Florida.

MIS 5d-a terrestrial equivalents from western to eastern Ukraine: chronology, and palaeoclimate derived from palaeosol and pollen successions

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The most complete Early Glacial sequences were formed in palaeogullies cut during MIS 5e. Detailed studies of such sites (including palaeosol catenas) in the forelands of the Carpathians, the Poltava Plain and the Donetsk Upland allowed long distance correlation of climatic events and environments. The A horizon of the upper soils of MIS 5e (TL 110 ka, 108 ka) is the lower limit of the MIS 5d-a sequence, whereas the loess (TL-dated 60 ka, 67.5 ka and 70 ka) delimits it at the top. During MIS 5d and MIS 5b, thin silt beds formed in the west under a tundra-like environment; there was intensive development of ground wedges and cryolamination. These, sand wedges and involutions were formed in the tundra-steppe of central Ukraine (particularly abundantly during MIS 5b). In MIS 5d, sediment re-deposition and cryogenic channeling were common. In the east, during both stadials, thin loesses accumulated in boreal grassland, and desiccation fissures occurred frequently. Involutions and cryolamination did not develop because of lack of ground moisture.

During MIS 5c, pedocomplexes included lower grey forest soils formed under birch and broad-leaved woodland (TL 98 ka, 95 ka) in the central region, and Cambisols under forest-steppe in the east. The upper soils were Chernozems, formed in mesophytic steppe, in the east - grassland (TL 90 ka). The MIS 5a soil successions consisted of lower forest-steppe Cambisols (85 ka, 82 ka) in the central region and Calcaric Cambisols in the east, both followed by upper Chernozems, formed under grassland (78 ka). In the west, Luvic Cambisols of MIS 5c and 5a, with Middle Palaeolithic layers, developed under mixed forest. The proportion of broad-leaved trees was small, particularly during MIS 5a.The climate was transitional from temperate to boreal in MIS 5c, and south-boreal during MIS 5a. Aridification progressed from the beginning to the end of both MIS 5c and 5a. Short cool and dry events, identified only by pollen data, mark the time between the formation of the lower and upper soils of both pedocomplexes. Reduction of woodlands occurred and broad-leaved trees disappeared. Continentality increased eastwards during all sub-stages.

The Pleistocene Sardinian composite marine terraces. Insight on sea level and tectonic interplay to reconstruct the recent geodynamic evolution of Western Mediterranean.

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Despite Sardinia Island being located in the centre of an active geodynamic puzzle, the western Mediterranean region, it has been considered tectonically stable since the Early Pleistocene. However, a light tectonic instability of the Island, possibly related to the isostatic disequilibrium of its lithosphere, has been recognized and testified by low-magnitude earthquakes, vertical movements and displaced geomorphic features associated with an ongoing uplift.

The Sardinia coast hosts several Pleistocene shallow marine deposits mostly related to the Marine Isotopic Stage (MIS) 5e highstand (116-126 ka) and placed at +5/9 m above the present sea level. However, chrono-stratigraphic reviews of Pleistocene marine successions have recently highlighted the superimposition of two o more sea highstands, particularly the stratigraphic superimposition of MIS 5c (~100 ka) on MIS 5e, both placed above the present sea level. However, this conflicts with the globally accepted sea-level curve, which described the MIS 5c at around -22 m below the present. Thus, the composite nature of marine terraces suggests the possible interplay between regional tectonic and sea level changes.

The evidence raises different questions: i) Is the highstand of MIS 5c substage well constrained in amplitude and elevation respect to present sea-level positions for the Mediterranean area? ii) Is the Quaternary Relative Sea Level curve of the Mediterranean characterised by unrecognised high-frequency sea-level oscillations below the sensitivity of presently available dating methods? iii) Has the western Mediterranean area been characterised by undetected regional versus local tectonic activity during the Pleistocene?

Answering these questions will open new scenarios on the Quaternary geodynamic evolution of the western Mediterranean during the last 300 ka.

Early Weichselian deposits in the Amersfoort Basin (NL): understanding sedimentary environments, paleogeography and paleoclimate during MIS 5d-a

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Eemian and Early Weichselian (MIS 5) deposits are exceptionally well preserved in the up to 200 m deep glacial basins that were formed in the southern North Sea Basin during the Saalian Drenthe substage glaciation (MIS 6). As such, these basins provide an excellent opportunity to study the sedimentary record from this time interval at the boundary between the marine and terrestrial realm. Internationally renowned research by prof. W.H. Zagwijn focused on the Eemian marine deposits and turned the Amersfoort Basin (central Netherlands) into the informal stratotype of the Last Interglacial (MIS 5e) in North-Western Europe. The overlying Early Weichselian sedimentary succession (MIS 5d-a), however, received less attention, although this 10 m-thick stack of alternating clastic and organic deposits reflects dramatic environmental and climatic changes. As part of a marine-terrestrial correlation project, we present new multi-proxy results from two recent high-quality sediment cores in the Amersfoort Basin, focusing on the Early Weichselian record.

The undisturbed sediment cores extend down to the base of the glacial basin and were analysed in detail. Granulometric and geochemical data were obtained, selected intervals were studied with biostratigraphic methods and optical dating was performed. There is generally a good agreement between the new cores and classic research. However, new analysis techniques and high-quality core material enable a much better insight in the sedimentary properties of the deposits.

Our results show that Eemian marine highstand deposits grade into coastal peat deposits, reflecting relative sea-level lowering, the onset of colder conditions and associated floral change. The next cold phase (MIS 5d) is characterised by sandy and loess-like deposits with frost cracks. Further upward two organic layers with arboreal pollen testify to the temporary return of mild conditions. These two organic intervals are separated by a thick loam layer (MIS 5b) and are correlated to Brørup (MIS 5c) and Odderade (MIS 5a), respectively. The sequence is capped by fluvio-aeolian deposits with ice-wedge casts (MIS 4).

Ultimately, this multi-proxy research gives better insights in the interaction of climate, landscape and ecosystems in the transitional period between the warm-temperate Last Interglacial and the severe cold of the Last Ice Age.

Identification of the Los Chocoyos supereruption in polar ice and marine sediment cores: climate and stratigraphic implications.

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The Los Chocoyos supereruption (LCY) of Atitlán Caldera, Guatemala is one of the largest volcanic events of the last 100,000 years, depositing one of the most widespread Quaternary tephra marker horizons in the Eastern Equatorial Pacific (EEP) and Central American regions. A recent zircon-rim radiometric age estimate of 75 ± 2 ka (1σ) suggests LCY is several thousand years younger than the previously adopted sediment stratigraphy age of 84 ka. This new age is also within error of the Younger Toba Tuff supereruption (YTT; 73.7± 0.3 ka (1σ)), and transition to Greenland Stadial 20 (GS-20; 74.1 ka), bringing into question the role of supereruptions in global climate shifts.

Identification of tephra shards associated with volcanic aerosol peaks in polar ice cores can robustly tie the deposit to an eruptive source, providing an independent, well resolved eruption age estimate. Here, we perform major oxide analysis of tephra found in both Greenland and Antarctic ice cores associated with a large volcanic sulfate deposit at 79.5 ± 1.7 ka (AICC12; Antarctic Ice Core Chronology 2012). We found 6 tephra shards (2 in Antarctica and 4 in Greenland) which are consistent with LCY geochemistry. In addition, we identify LCY ash at 80.5 ± 0.9 (2σ) in EEP marine sediment core V19-30, one of the best resolved stratigraphic $\delta^{18}O$ records in the region.

The agreement between our ice and sediment core ages provides a new, robust age for this key chronostratigraphic marker. Based on this finding, we can rule out back-to-back YTT-LCY supereruptions at the onset of GS-20, indicating LCY is not a driver of sustained (longer than decadal) global climate perturbations.

Climatic record of the Upper Pleistocene (MIS6-MIS2) in terrestrial sediments at the Parchliny site, central Poland against the bentic isotope records

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The upper Pleistocene stratigraphy has been well documented in numerous terrestrial profiles in Poland. Unfortunately, most of the positions contain fragmentary record, therefore it is difficult to find a model position for the stratigraphy of this period. Documented profiles "Parchliny 2012", "2014" and "2016" profiles in the Bełchatów Lignite Opencast Mine are the record of overlapping but continuous sedimentation within the same palaeolake. On their basis, we traced the rhythm of palaeoenvironmental changes from the Late Saalian across the Eemian interglacial to Pleniglacial (MIS6-MIS2). Three phases of changes have been distinguished within the Late Saalian (MIS6). The first phase was related to the rapid melting of a block of dead ice buried in the tills and the formation of a lake reservoir with no traces of vegetation cover. The second phase was gradual, with a mosaic of tundra correlated with Stadial 1. The third phase indicate improvement of climatic conditions, with sparse pine-birch boreal forest communities correlated with the Zeifen interstadial and subsequently Kattegat stadial, expressed by coexistence of forest communities and open park tundra. Eemian interglacial has been documented in complete with a well-marked climatic optimum – oak and hazel phase and a clearly marked phase of hornbeam-lime and spruce-fir forests. Stadial and interstadial phases have been captured within the Early Weichselian (MIS5e-d) and Pleniglacial (MIS4-MIS2). They indicate the transitions from sub-arctic tundra vegetation and grassland to boreal forest communities.

Palynologically documented climatic oscillations of different rank are confirmed by the LR04 bentic stack (Lisiecki and Raymo, 2005).

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Session 166: Quaternary palaeohydrology: from the reconstruction of spatial impact of extreme events to long-term changes in catchments and landscapes

Rapid laminated clastic alluviation associated with increased Little Ice Age flooding co-driven by climate variability and historic land-use.

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The discovery of exceptionally well-preserved visible clastic laminations in deep alluvial sediments at Kempsey, Worcestershire (UK), provides the opportunity to analyse and understand localised micro-depositionary conditions in the River Severn. At the sample site over 4.5m of sandy silt alluvium has accumulated on the floodplain, and Optically Stimulated Luminescence (OSL) dating of the upper 2.25m demonstrates accretion from the late 14th century AD onwards. High resolution multi-proxy sediment analysis using Loss on Ignition (LOI), magnetic susceptibility, particle size, ITRAX and portable XRF (pXRF) demonstrate clear variations in depositional history. Between AD 1380-1550 overbank alluviation was driven by small-scale flood events, with negligible effect from climatic conditions during the Spörer Minimum (AD 1460-1550). After AD 1550 the magnitude of flooding events increased and by AD 1610, the start of the visible sub-centimetre laminations, the accumulation rate regularly exceeded 3mm yr-1, which subsequently increased to 4.5mm yr-1 between AD 1690-1710, and 3-3.5mm yr-1 between AD 1790-1840 before alluviation was altered by the construction of a major embankment. The greatest extent of coarse alluvial deposition and increased accumulation rate occur concurrently with periods of climatic instability associated with the Maunder (AD 1645-1715) and Dalton (AD 1790-1820) Minima, the periods of largest historical floods and during the intensification of arable cultivation across the middle Severn catchment. Together these suggest that climate variability and land-use intensification were fundamental in driving the character and behaviour of the River Severn, and may have played a causal role in the development of settlement within the historic core of Kempsey.

Towards the Map Application Putting the Historical Floods into Context

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The aim of this contribution is to present the recently created "Map of Extreme Floods" (MEF) ESRI application, as an extremely useful tool for numerous purposes related to historical hydrology. In contrast to usually applied flood extreme databases, undoubtedly very useful for fast searching and selection of information based on simple classification, but lacking geographical instruments, the MEF places the above into spatial and temporal frameworks. Actually, the MEF application enables to put the fundamental information on European historical floods, i.e. the exact location and datum, into broader spatial and temporal context. The maps created by this tool form the reliable fundament for detailed exploration and including of additional data. The principal MEF application aims are: (i) archiving, (ii) verification, (iii) corrections, (iv) addition of further data and information, and (v) providing information for both scientists and public. The performance of the MEF application is documented by selected historical extreme flood events, analogical to these of 1997, 2002, and 2013.

Decoding of Alpine flood types since 1480 based on the temporal-spatial integration of natural, documentary and instrumental data series

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Under the umbrella of Work package 2 of the PAGES Flood Working Group an innovative multidisciplinary methodology was designed that integrates multi-archive datasets from floodplain and lake sediments, tree rings, lichens, historical documentary evidence, hydraulic infrastructure, and archaeological sites to perform robust centennial-long reference flood records for the Bernese Swiss Alps (Schulte et al., 2019). In the present paper we show how to investigate systematically the temporal-spatial pattern of floods and atmospheric dynamics from 1480 to 2011 CE in order to obtain a 4D flood model which provide holistic insights into flood generation in high mountains.

The paleoflood maps of the Bernese Alps show the following spatial patterns: i) all catchments (1480, 1831, 1851, 1977, 2005, and 2011) ii) western catchments (1575, 1651, 1711, and 1852); iii) northern catchments (1511 and 1566), iv) eastern catchments (1762) and v) local catchment flooding (1678, 1791, 1873 and 1933). According to the sequences of atmospheric dynamics generated from reconstructions (20th Century Reanalysis Project, 1836-2011) and paleoclimatic models (Last Millennium Ensemble Project, 1480-1836), different climatic patterns of flood episodes were classified: i) atlantic Mediterranean (aM; 1480), ii) Mediterranean (M; 1511, 1575, 1651, 1762, 1791, 1933, 2005), iii) Mediterranean winter (wM; -NAO; 1678, 1711), iv) Central European (CE; 1566), v) mediterranean Atlantic (mA; 1831, 1852, 1873 2011) and vi) Atlantic-Mediterranean (AM; 1851, 1977).

Subsequently twenty-two data series of flood intensities, local atmospheric and environmental conditions and climate proxies were normalized and Multivariable Analyses were performed to define flood patterns. These patterns were compared with maps of paleoflood incidence and composite Sea Level Pressure to investigate regional flood forcing, and types and changes through time since 1480 CE. From 1500 to 1762, for almost three centuries of the Little Ice Age, prevailed the Zonal flow type, followed by the Atlantic type from 1811 to 1852 during late cool pulse of the Little Ice Age. During the moderate climate pulses 1791 and since 1873 (20th-21st century warming trend) the Mediterranean type dominates. The timing and opposite pattern of the 1480 and 1977 flood episodes of the Atlantic Blocking type needs further investigation.

Combining multiproxy records and hydrological modeling to improve the reconstruction of past flood events in south-eastern Spain

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The analysis of the extent and magnitude of past floods and the identification of the main triggers that cause large floods are essential to understand the impacts of climate change and the effects of human intervention in the fluvial systems. Our study carries out a reconstruction of flood events in the Almanzora catchment, located in the southeast of Spain. We analyze the major large floods from the last 120 years, that have affected various settlements and caused the loss of human lives and/or significant damage to buildings and infrastructures.

For the reconstructions, we included instrumental data, flood marks on buildings and bridges, description of flood areas and water levels in historical documents and biomarkers of flood levels based on lichenometric analyzes of rocky surfaces exposed to water flow. These multiproxy records allowed the estimation of the maximum flow heights in various settlements along the main river course and in some important tributaries (such as: Huitar, Albox and Almajalejo).

The results show that over the last 120 years, this region has experienced some extreme precipitation events, usually related with blocking atmospheric circulation patterns, that produced very high peak discharges. For the reconstruction of the maximum flood discharges we ran a 1D hydrological model and 2D models in specific key areas where a detailed characterization of the hydraulic behavior of the flow was necessary. The most catastrophic event of the last 120 years occurred in October 1973, where we estimate a peak discharge higher than 5000 $m^3 s^{-1}$ on the Almanzora River. This extremely high discharge correlates with the devastating consequences of the event in the main settlements and in infrastructures along the Almanzora river and major tributaries. Other important floods occurred in 1900, 1924, 1977 and 2012, but with a lower magnitude than 1973 flood event.

This study shows that the integration of different flood proxies can generate detailed reconstructions of past floods and thus improve current estimates of flood risk, particularly in areas where vulnerability to flooding is high. These reconstructions also provide new insights into the frequency of large-scale flooding in the Mediterranean region over the past 120 years.

Increased hydrological droughts in the Irrawaddy River and Upper Yangtze River since the 1850s inferred from tree-ring oxygen isotope records

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Ongoing global warming has a strong influence on regional hydrological cycles. The Irrawaddy River and upper reaches of the Yangtze River which are affected by Indian summer monsoon are highly vulnerable to extreme hydrological droughts and floods, but a lack of long-term streamflow observations has limited our understanding on global warming influences. Here, we establish two annually resolved and absolutely dated tree-ring oxygen isotope records, and use them to reconstruct the summer streamflow history of the Irrawaddy River and upper reaches of the Yangtze River during the period of 1617-2017 and 1260-2017, respectively. We found a trend toward dry conditions in the region with tendencies for an increased drought probability since around 1850s. Especially, the frequency of hydrological droughts in recent decades has been outside the envelope of natural variability of extreme hydrological droughts. The recent increase in the frequency of hydrological droughts is consistent with the observed trend toward a weaker Indian summer monsoon and increasing temperatures. Weaker transport of low-level moisture and greater evaporation caused by global warming have contributed to the increase in extreme hydrological droughts. Our results thus provide a long-term context for observed hydrological changes and suggest that the Irrawaddy River and upper reaches of the Yangtze River will experience more frequent and severe extreme events as a consequence of increasing greenhouse gas emissions.

Birth and death of the alpine Lake Tschingel. A 50 year-long multi-archive flood reconstruction in the Swiss Alps

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Linking paleoflood-records (e.g. fluvial deposits, lake sediments, etc.) with instrumental data (precipitation, temperature and discharges) and historical information (reports, maps and photographs) is frequently applied in paleohydrology. However, one of the main challenges is to integrate time series of different temporal resolution and involved physical process. Furthermore, the precision of geochronological models of the last 150 years can be a critical issue.

In this work, we present the sedimentary and geochemical records obtained from the Tschingelsee Lake located in the Berner Oberland (1150 m.a.s.l.; 46° 33.170 'N; 7°44.661' E). The lake was formed by the damming of the Chiene River by a debris flow that occurred during the night of August 18th 1972. Since 1972, the Chine delta grew rapidly and today the accommodation space is almost filled with sediments. The short distance between the lake and the Kiental meteorological station as well as the high-resolution lake sediments allow us to analyze the relation between rainfall events, catchment hydrology and sedimentary flood records.

The 3m-long sedimentary core shows different textural facies covering the last 50 years. The geochronological model since 1972 was performed by the attribution of sedimentary facies to known extreme weather episodes, flood events or geomorphological changes. The changes in the lacustrine and fluvial-deltaic depositional system were inferred from aerial images, photographs, reports and witness testimony.

Subsequently, the sedimentary flood data series (Ca/Ti and Zr/Ti ratios) were cross-correlated with the precipitation data (mm/24h) obtained from the Kiental (930 m a.s.l.) and Kandersteg (1178 m a.s.l.) meteorological stations, and the discharges (m3/s) of the Kander river at the Kander-Hondrich (650 m a.s.l.) gauging station.

This work contributes knowledge about the effects of global warming on mountain hydrology, climatic forcing of sediment yield and precipitation-sedimentation thresholds in small alpine catchments. Finally, the approach highlights the possible limitations of the accuracy of centennial or millennia-long paleoflood records from lake sediments.

Flood Meteorology, Hydrology and Geomorphology of the Upper Godavari River: Western India

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High magnitude floods during monsoon are considered to be India's recurring and leading natural disaster. Such floods are extremely significant events in terms of human impact and geomorphic effectiveness. The Godavari River in Peninsular India is characterized by one of the most intense flood regimes. The river has experienced largest peak on record in India of 100000 m^3s^{-1} in 1986. In the present paper an attempt has been made to understand flood meteorology, hydrology and geomorphology of the Upper Godavari River (UGR), of western India. To understand flood hydrometeorological situations associated with floods on the UGR, analyses of synoptic conditions of large floods were carried out. This encompasses analysis of rainfall variability and floods and analysis of storm-tracks. Annual rainfall data were obtained for 142 years. The results signify that the interannual variability was characterized by increased frequency and magnitude of floods primarily after 1930s and majority of large floods were connected with low pressure systems. In order evaluate flood potential of the UGR, unit discharges (Q_u) and flash flood magnitude index (FFMI) were computed. The annual maximum series data were procured for six gauging sites. The values of Q_u range from 0.88 to 6.16 $m^3s^{-1}km^{-2}$ indicating potential of large floods on the UGR. The FFMI values range between 0.27 and 0.46 which show flashy and variable nature of floods and possibility of noteworthy geomorphic work during large floods. To find out effect of infrequent and large magnitude floods, parameters of flood hydraulics and hydrodynamics such as unit stream power (ω), bed shear stress (τ), Froude number (Fr), Reynolds number (Re) and critical velocity for inception of cavitation (Vc) were computed. The highest values for ω and τ are 8273.5 Wm^{-2} and 609 Nm^{-2} respectively. These values reveal unusually high ability to erode and transport sediments. The Fr <1 and >1, indicating subcritical and supercritical flows. High values of Re reveals extremely turbulent flood discharges.

Palaeoflood records of Bharathapuzha river, Kerala, South India and its implications to climate

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River Bharathapuzha is the second-largest perennial river in Kerala. The study focuses on the middle to late Holocene fluvial processes and flood-climate relationships utilizing the fine-grained (sand-silt-clay) stratigraphic sequence of slack water deposits (SWD) as palaeostage indicators on a bedrock river system. These stratigraphic indicators are important physical evidence of past floods that occurred in the region and their relation with climate, and land-use needs to be analyzed. Understanding the threshold levels of the largest floods in the past is crucial for assessing recurrence intervals of major floods, their geomorphic response, planning large-scale engineering structures, and obtaining a long-term perspective of major floods in the catchment. Five sections were excavated at different morphological units of the river system, which include over-bank, point-bar, natural levees, river terraces, flood benches, etc. Optically stimulated luminescence (OSL) dating was used to establish the chronology, while the granulometric studies and primary sedimentary structures were used to determine the characteristic stratigraphic indicators of SWD. The channel morphology was assessed and geometry and valley cross-section was studied using a close-interval total-station survey. The boundary between non-flood sediments and flood sediments was established based on the stratigraphic signatures of distinct clay-silt litho-unit formed during the waning stage of the flood, macro-debris, and palaeosols. The results of OSL dating of SWD show large-scale floods during 1830- 1882 AD. It is the period that coincides with the end of the Little Ice Age (LIA). The proxy records had shown weakened summer monsoon during LIA due to cool and dry climatic conditions. The OSL ages of samples from a flood bench at the banks of the palaeochannel have shown the age of deposition during 1956 AD. The upper terrace of this channel gave a depositional age of 1555 AD. The palaeofluvial terrace of 3.0 m thick adjacent to the present-day river course shows an age of deposition during 5.1 ka, implying a lateral migration of channels by progressive abandonment since the middle Holocene. The SLW and fluvial terraces show varying hydrological conditions and enhanced flooding of rivers in south peninsular India during the last two centuries.

Calibration of the high-resolution archive for past extreme events recorded in Lake Hallstatt with instrumental and historical data over the last 50 years

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Lake Hallstatt is an inner-alpine clastic lake with a high-resolution sedimentary archive with mm-to-sub-mm-scale laminated background sediment with “sub-annual” resolution (sedimentation rates of ~0.5 cm/yr) spanning the entire Holocene. The area is well known for its Alpine landscape and well-documented human settlement history within the UNESCO World Heritage Cultural Landscape Hallstatt-Dachstein/Salzkammergut, Austria. Towards reconstructing impacts and understanding trigger-consequence relationships of extreme events on long timescales, detailed multi-proxy datasets of the Lake Hallstatt sedimentary sequence need to be “calibrated”. This is accomplished by robustly linking the lake-sediment stratigraphy to documented instrumental and historical data points to evaluate trigger processes of extreme events, their consequences for the landscape and society on prehistoric time-scales.
Here, we present a calibration study of the sedimentary archive of the last 50 years. The sediment cores are studied through visual core description, multi-sensor-core-logger data, X-ray computed tomography, elemental data (micro-X-ray fluorescence (XRF) mapping and XRF scanning) and grain-size measurements. These proxies are used to fingerprint event deposits (e.g. floods and debris flows). In combination with an age model based on radionuclides, this allows to link identified event deposits to instrumental and historical data of the last 50 years. To reduce human bias in data evaluation, multivariate statistics (e.g. principal components analysis and clustering) and time series analysis are pursued to help discriminate event deposits and their underlying trigger mechanisms. As a result, we identify and link flood deposits to documented floods occurring in 2013, 2002, 1997, 1991 and 1981 and to instrumental data such as daily precipitation, river discharge, flood height, and lake level. Furthermore, monthly lake geochemistry data allows for tracking the potential sedimentary fingerprint of two brine spills (related to salt mine activity) that occurred within the Lake Hallstatt catchment area and were reported to affect the limnological system. Biogeochemistry data of the sediment cores, including total carbon, total nitrogen, bulk carbon isotope, and biomarker, are investigated to identify salt-intrusion proxies for meromixis and low-oxygen bottom waters. This may shed new light to further explore the salt mine activities of the Hallstatt region in prehistorical times.

Developing flood histories using centennial to millennial floodplain sediment archives in contrasting New Zealand catchments

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Recent extreme flood events in New Zealand have demonstrated the impacts and risks posed by high-magnitude, low-frequency flooding, the likes of which have not been previously recorded, emphasising the urgent need for further research to extend flood series to contextualise these events and improve prediction. Floodplain environments offer an ideal archive for flood series extension by acting as sediment sinks during flood events, directly recording episodes of flooding and catchment erosion as well as the influence of recent human induced landscape change. This research seeks to understand the timing, magnitude, origin and drivers of flooding and erosion events in two contrasting catchments. The Whanganui, North Island, is confined by steep, narrow valleys for much of its western and lower catchment, underlain by weakly lithified sandstone, siltstone and mudstone of the Whanganui Basin; while the north-eastern part of the catchment drains the central volcanic plateau. The Whanganui sediment archive is located in a valley cutoff (Atene) in the lower catchment. The Ōreti, by contrast rises in the foothills of the Southern Alps in the South Island and drains less erodible greywackes and schists in a largely unconfined valley setting. Infilled meander cutoffs provide the sediment archive in the lower Ōreti valley. Particle size analysis (PSA), geochemical analysis (XRF ITRAX core scanning), computed tomography scanning (CT) and magnetic susceptibility identify and distinguish flood units. Magnetic susceptibility and geochemical analysis also distinguish erosion sources. Initial basal radiocarbon dating indicates the ~12 m cores recovered from Whanganui date from 4458 ± 24 cal yr BP and the 2.5 m cores from Ōreti from 149 ± 20 cal yr BP. Spanning approximately ~4.5 ka years, the Whanganui archive tracks the impacts on erosion and flooding of late Holocene climate change, landscape response to the 232 ± 5 AD Taupō eruption and human arrival and settlement within the catchment. The Ōreti floodplain captures a more recent high-resolution record of flooding and erosion, particularly the influence of human settlement and agriculture within the catchment. This research contextualises contemporary flooding and erosion problems within a longer, pre-historical timeframe, helping to support better management of rivers and their catchments.

Pleistocene megafloods in the Altai-Mountains – recent challenges for reconstruction

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In Pleistocene times, the Russian Altai Mountains located in southern Siberia experienced a typical valley glaciation. In the headwaters of the River Ob, the valley glaciers blocked the course of rivers and generated ice-dammed lakes with repeated outburst floods. Field evidence is frequently described and interpreted following different, partly controversial concepts.

Due to a continuously increasing amount of new contradictory dating results, the chronology of the outburst floods recently became confused. By combining different locations with varying age estimations, the potential number of floods of different origin and pathway increased while obvious field indicators for plausibility are occasionally left out of consideration. In addition, a closer look for mineralogical sample quality in combination with a critical view on methodological challenges of applied dating techniques might help for the judgement of the quality and reliability of the controversy results.

Another challenge is the water balance of the glacial lake. The recent climate of interglacial conditions within the catchment is semi- to full-arid with mean annual temperatures below zero degrees, but short hot summer times. From Pleistocene times, climate indicators are missing due to environmental conditions in the glaciated high mountain environment. Despite that in Pleistocene times the climate might have been even harsher, the conditions must have allowed the repeated refill of the lake within the time span between the outburst floods. First modelling approaches are presented for further discussion.

The structure of the Moksha River floodplain as a key to the Late Pleistocene history of the valley development

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1. Individual researcher

The noticeable geomorphic feature of the Moksha River valley (middle Oka River basin) is the occurrence of numerous large palaeomeanders that evidence a several fold rise of river discharges. Such large meandering palaeochannels (macromeanders) are typical for the river valleys of the East European Plain. To establish the history of the Moksha River valley development, we studied the key site in the lower part of the valley. Using the results of mechanical coring, geomorphological and lithological analysis, and radiocarbon AMS-dating we reconstructed few stages of the Moksha River valley development in the end of the Late Pleistocene. About 40-30 ka ago the increase of the river runoff associated with climatic changes led to the river incision deeper than the present level. After that the drying up of the climate and a lowering of the river runoff led to the filling of the valley (the strongest drying was in LGM time, about 23-20 ka ago). Then 18.5-12 ka ago the river runoff increased again and caused macromeanders formation and widening of the valley bottom. Modern wide high floodplain was formed at that time. In the Holocene runoff decreased and the channel parameters became close to the modern ones and the meandering belt of the river narrowed.

Magnitude and frequency of floods in the Judean Desert streams, Israel, using palaeoflood hydrology: Understanding the past to prepare for the future

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The Judea Desert constitutes a distinctive hydrological region characterized by steep bedrock ephemeral streams draining eastward to the Dead Sea Valley. The hydrological data for these streams are partial and scarce, leading to poor estimation of magnitude and frequency of floods. The lack of data is particularly significant when it comes to risk assessment for infrastructure. The current study is based on Palaeoflood Hydrology which uses geomorphological evidence for past real floods that accumulate in typical natural traps, along the course of the streams for hundreds and thousands of years. Those evidences indicate on the minimum water elevation of the flood enabling discharge calculations using HECRAS hydraulic engineering software. The ages of the floods are determined by radiocarbon and OSL dating of the flood deposits. These hydrological palaeoflood data enables to reconstruct the history of the floods in the streams including the largest event that occurred in the stream during the last hundreds to thousands years. By combining these data with measured and historical data (if any), a long, solid database can be reconstructed. The largest flood that occurred in the stream can serve as a control on regional envelope curves and rainfall runoff models such as PMP-PMF.

The streams in this study are: Darga (71 km^2), Arugot (217 km^2), Ze'elim (250 km^2) and Rahaf (55 km^2), along with Heimar (450 km^2) and Ashalim (35 km^2) from previous study. The duration of the reconstructed palaeoflood records are 210, 410, 250, 700, 300 and 7600, respectively. The maximum reconstructed palaeodischarges were 300, 830, 900, 1250, 1100 and 400 m^3s^{-1}, respectively in relation to the maximum measured peak discharges of about 140, 530, 680, 525, 540 and 100 m^3s^{-1}, respectively.

Frequency analyses using Max and FLDFRQ3 programs with the integrated data (systematic and palaeo) shows is some cases a significant decrease in the discharge values for low probabilities, while in others, the opposite trend was obtained. In all streams, the values for the integrated data are significantly more reliable as indicated by the value of the standard error.

Late-Quaternary paleohydrological changes in the alluvial system of Isonzo River (Northern Adriatic)

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In the last decades important progress has been done in understanding the evolution of the depositional systems forming the alluvial plains of NE Italy by the main rivers draining the south-eastern Alps. Anyhow, very little is known about the Isonzo, a river with a catchment extending for 3400 km^2 in the Julian Alps, mainly in Slovenia, but forming the eastern-most sector of the alluvial plain of Northern Italy.

Thanks to the analysis of Lidar-derived DEMs, remote-sensed images, stratigraphic cores and geophysical soundings, both in the mainland and in the seabed of the Gulf of Trieste, our work reconstructed the different channel belts activated by the stream during the last 20 ka cal BP. In particular, we documented and characterized the dramatic palaeohydrologic changes experienced by the river in response to climate changes and sedimentary connectivity with the mountain catchment.

During the final part of LGM the river formed an alluvial megafan extending in the whole Gulf of Trieste and the very last channel belt of that phase was strongly constrained by the setting of the bedrock and flowed the present coastal boundary of the Karst from Monfalcone to Trieste, Koper and Piran. The mountain basin was occupied by a glacier at the LGM peak and, since the beginning of the deglaciation and glacial withdrawal, most part of the sediment was trapped within the valley because of landslide damming. In the starved alluvial plain a single incision formed from Gorizia, confined by 40 m high scarps that were progressively decreasing, until disappearing 20 km downstream. Incised filled valleys are documented through boreholes in the present coastal plain. The largest one reached a depth of 20 m and a width of 2 km and was filled at the bottom by sands and gravels, but estuarine environments occupied those alluvial depressions since early Holocene. Along the coast the incised valleys have been filled especially in the last millennia, when the sedimentary flux from the mountain was reconnected to the plain. This setting allowed the Isonzo to form several fluvial ridges in its distal sector, characterizing a new aggradational phase.

Paleo-drainage network identification of Central Kerala using remote sensing and machine learning techniques: implications on palaeogeography

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Fluvial depositional systems are complex transient sedimentary bodies originated from the erosion of catchment over a time period. They consist of multiscale landforms and displays variety of sedimentary architectures. Paleo-drainage networks are such important fluvial landforms that evolved as a result of the fluvial system's response to natural/anthropogenic forcing. Further, the ancient river channels act as conduits of flood waters during extreme weather events. Mapping the palaeo-channels in the area have thus become a prerequisite in hazard management to mitigate large scale floods. Conventional remote sensing techniques based on multi-temporal satellite data sets of a specific location were found to be useful in identifying ancient hydrological systems globally. However, due to the difficulties in processing large datasets, conventionally a single satellite image captured in a particular time period was used for the purpose thereby limiting their ability to identify features in complex and dynamic landscape scenarios. In this study paleo-drainage networks of Periyar-Chalakudy River basin of central Kerala in South India were studied using vegetation indices and image enhancement techniques of a multi-spectral and multi-temporal dataset. Landsat 5 data of twenty-five years were compiled and processed for identifying paleo drainage systems using a Java Script code in the Google Earth Engine Platform. The landward extension of South Kerala Sedimentary Basin (SKSB) in Central Kerala of South India had experienced episodes of fluctuating sea-level and climate throughout the Quaternary. The present alignment of Kerala coast and coastal landforms are consequences of the Holocene land-sea interactions. The study has allowed identification of paleo-drainage networks associated with Periyar and Chalakudy River systems which is the largest river network in Kerala. Most of the identified channels presently occur as misfit streams with wider valleys possibly implying their genesis in a distinct hydrologic and climatic condition than present.

Keywords: Paleo-channels, multi-temporal data, Vegetation Indices, Google Earth Engine

Session 169: Quaternary Proglacial Lakes: Sediments, Landforms, Impacts

Subaqueous geomorphology of Lake Whakatipu, New Zealand, and geomorphic hazard implications

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Alpine lakes are dynamic environments with a range of geomorphic hazards. These hazards are typically facilitated by steep slopes, high seismicity, and extreme climate, which create high sediment loads and rapid post-glacial evolution. Alpine lakes also attract development, often being the most densely populated parts of alpine landscapes. Few studies have evaluated the full range of subaqueous and lake margin geomorphic hazards of alpine lakes. The growing availability of high-resolution bathymetric data, particularly for the little-explored Southern Hemisphere lakes, has made such evaluation possible.

High-resolution bathymetric data for an 80-km long glacial trough lake (Lake Whakatipu, New Zealand) was acquired in 2019, which we used to map the subaqueous geomorphology. This mapping guided landslide-triggered tsunami modelling and repeat bathymetric and seismic refraction surveys in 2021. We mapped a 2-km wide lake-head delta that connects to a 39-km long sinuous subaqueous canyon incised into lake sediments. Crescentic-shaped bedforms dominate the subaqueous delta and canyon, with wavelengths of up to 150 m. There is evidence of active canyon erosion and deposition, and canyon wall collapse within the past 2 years. The lake margins consist of sediment-draped subaqueous slopes which are extensively gullied, and gully growth could potentially undermine the lake shore. Bedrock scars mapped along the lake margin and features buried within the lake sediments, provide evidence of past rock-slope failures. Scarps on bedrock slopes are evidence of ongoing instability and potential failure. Tsunami modelling for three mapped landslides suggested maximum wave heights could have exceeded 5-m at the shoreline.

The availability of high-resolution bathymetric data has provided new insights into the potential geomorphic hazards of dynamic alpine lakes. Identification of these geomorphic hazards is critical in order to reconcile the ongoing population growth and investment in alpine lake settlements with the high hazard exposure within these dynamic environments.

Glacial lake outburst floods in southern Norway during the Early Holocene

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Landform mapping using high-resolution LiDAR data has confirmed the presence of a suite of glacier-dammed lakes that existed along the retreating Scandinavian Ice Sheet in southern Norway at the end of the last Ice Age. Some of the lakes drained catastrophically along or beneath the remnant ice sheet during deglaciation. In this talk we present the geomorphological imprints of the outburst floods from two large glacial lakes – Store Dølasjø (A: 480 km^2, V: 80 km^3) and Nedre Glomsjø (A: 1300 km^2, V: 140 km^3) – that existed in southern Norway during the Early Holocene. The landform record related to the Store Dølasjø outburst flood comprises for instance clusters of large dune-like bedforms and longitudinal bars. Similar dunes seem to have formed not only south of the remnant ice sheet, but also within the glacial lake itself during the outburst flood. The landform record related to the Nedre Glomsjø outburst flood is more varied and comprises different kinds of large-scale bedforms, palaeochannels and obstacle marks found over a large region. Sections through some of the bedforms reveal coarse-grained, unsorted and consolidated sediments that locally show steeply dipping large-scale foresets. The outburst flood deposits indicate high sediment transport capability and rapid deposition. We also present the results of hydrodynamic simulations of the outburst flood from glacial lake Nedre Glomsjø, where approximately 100 km^3
of the lake drained in one event. Mapped high-water marks in the flooded region provide excellent constraints for the simulations, which suggest peak outburst flood discharges of 1.5-2 million m^3/s. Separate simulations of channelized drainage through an expanding ice-walled tunnel support the feasibility of this peak discharge estimate.

Pulling the plug – the role of ice-dammed lakes on the final demise of the Scandinavian Ice Sheet

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In northern Scandinavia, geological evidence pertaining unequivocally to the final deglaciation of the ice sheet is sparse due to largely cold-based decay. Furthermore, absolute dating constraints are woefully few, leaving the timing and location of final ice sheet decay still elusive. In the late stages of the deglaciation, however, extensive glacial lakes were dammed between the easterly retreating Scandinavian Ice Sheet (SIS) and the Scandinavian mountains to the west. Using LiDAR-data, we have discovered shorelines and other landforms relating to ice-dammed lakes over larger areas and in greater numbers than previously known, opening a treasure trove of palaeoglaciological information for reconstructing the final demise of the SIS.

With examples from all along the mountain range, we show how ice-dammed lakes were an intricate part of the deglacial dynamics, and how mapping and dating them offer a solution to these problems. We have reconstructed the full suite of ice-dammed lakes (n >400) along the length (>1000 km) of the mountain range. Starting as a multitude of smaller ice-dammed lakes, following ice-margin retreat they successively coalesced to form progressively larger lakes up to >3500 km^2 and 100s m deep. In many of these lake systems, we depict multiple stages of lake lowering, corresponding ice margin evolution and shifts in drainage, while cored sediments that capture glacial- to nonglacial lake transitions offer a chronology for these events.

With these reconstructions, we explore the impacts of lake filling and drainage on rates of ice margin retreat and positions of (in)stability. We find that catastrophic lake drainage events were coupled to ice-sheet partitioning, arising from a complex interplay between the rapidly retreating ice sheet and sub- and pro-glacial topography. Initial emergence of nunataqs following ice-sheet thinning funnelled ice flow into lower ground where enhanced ablation by calving in ice-dammed lakes effectively dissected the decaying ice sheet. Often depicted as one coherent ice mass, we now see evidence of recurring unzipping and partitioning of the ice sheet along the mountain range.

The evolution of glacial lakes Barlow and Ojibway was controlled by a single outlet throughout the last deglaciation: evidence from new lake-level reconstructions

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The retreat of the Laurentide Ice Sheet across northern Ontario and Quebec (Canada) was accompanied by a succession of glacial lakes that culminated with Lake Ojibway – a large ice-dammed lake that coalesced with Lake Agassiz late in the last deglaciation. The glaciolacustrine episode began with Lake Barlow that flooded the upper Ottawa River watershed and continued ice retreat led to the northward expansion of the lake and the development of Lake Ojibway north of the St. Lawrence River–Hudson Bay drainage divide. The history of Lake Barlow and its relationship with Lake Ojibway remain poorly known, notably regarding its temporal changes in elevation and extent. Previous work reported distinct lake stages, with lake levels controlled by a series of uplift-driven topographic (bedrock) outlets whose locations remain arbitrary. Mapping and elevation measurements of raised shorelines and deltas using LiDAR Digital Terrain Models (DTMs) covering the Barlow basin yielded an inventory of >5000 shoreline segments. Strandline elevations were corrected for the effects of post-glacial uplift using a DTM integrating the basin paleotopography (at 10.5 ka) to facilitate the reconstruction of lake levels. The new lake-level reconstruction indicates a regular lowering of the lake surface below the maximum limit of submergence, with no evidence for distinct lake-level stages (i.e., stability phases). Projection of tilt-corrected (sub-horizontal) lake levels suggests that the Lake McConnell Moraine in the south of the Barlow basin was the single outlet that regulated meltwater overflow towards the St. Lawrence River throughout nearly the whole glaciolacustrine episode. Comparison of Lake Barlow shoreline sequence with that of Lake Ojibway shows that the two lakes shared a common surface for most of the deglaciation – a connection that lasted until the first major lake-surface drawdown that led to the drainage of Lake Agassiz-Ojibway. These results eliminate the need for a succession of outlets to explain the evolution of Lake Barlow-Ojibway, in addition to bring new considerations on the connection between Lake Agassiz and Lake Ojibway in the late deglaciation, with attendant implications for the modeling of the meltwater volumes associated with the main lake stages that led to the final drainage.

Glacial Lake Outburst Flood from the Central Alps (N-Italy): from the Last Glacial Maximum to the deglaciation

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In glacial amphitheatres, proglacial lakes formed between moraine ridges, small fluvioglacial plains, and glacier fronts, represent potential sensitive sedimentary archives of environmental variations, especially recording the evolution of glaciers during the Last Glacial Maximum (LGM). Shifts in facies associations in glaciolacustrine deposits are a useful tool to disentangle advance and retreat phases of glaciers and their effects on the landscape. The sedimentary record of the LGM deglaciation at the southern foothills of the Alps, regionally dated between 24 and 17 ka, suggests the transition to the Late Glacial was accompanied by dramatic events, including landslides, ice calving, and glacial lake outburst floods. The investigation of glaciolacustrine deposits from the Adige River Glacial Amphitheatre (ARGA), a LGM multi-moraine ridges system located at the end of the Adige Valley (N-Italy), revealed specific glacier dynamics in the deglaciation. Inside the ARGA innermost moraine arcs, the glacial topography acted as a dam originating two separated ice-contact lakes, collecting meltwaters. Analysis of facies associations suggests deposition of sands and gravelly sands in proximal settings (close to the glacier fronts), and thinly bedded mud-prone facies in distal settings. The proglacial lakes were likely enclosed by the glacier fronts, moraine ridges, and older glacial deposits that obstructed the pre-existent Adige River canyon; the two separated lakes eventually coalesced together during the last phase of retreat. The available stratigraphic framework suggests that the boulders cropping out in the Venetian Plain deposits to the South of ARGA, coeval to the deglaciation phase, may represent megaclasts transported by a glacial lake outburst flood formed after the catastrophic 'unclogging' of the Adige River canyon from the glacial deposit occluding it. Results presented in this contribution add to understanding of the ARGA deglaciation phases and to the wider picture of the LGM-Late Glacial transition in the South-Central Alps.

Sole survivor? Holocene lacustrine evidence suggests Svalbard's most resilient ice cap survived warmer-than-present past conditions

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Record breaking warming and hydrological intensification throughout the Arctic stand as evidence that the region is experiencing extreme environmental change, yet future developments remain poorly constrained by models. Gaining more insight into these changes can help clarify their highly uncertain and counteracting impacts on glaciers, dominant drivers of sea-level change. The Quaternary sedimentary record of environmental responses to climate change during warmer-than-present intervals offers an opportunity to better constrain models and can provide context for future warming. We explore the potential of these records in a key area of the Arctic - northern Svalbard, where throughout the Holocene and beyond, the interactions between climate and the Åsgardfonna ice cap are recorded in the sediment archives of down-stream glacier-fed lakes.

The characteristics of the sediments accumulated in two of these lakes are analysed using a tested multi-proxy toolbox (i.e. CT scanning, XRF, XRD, grain size analysis, seismic data) that provides independent lines of evidence for the fine-grained and minerogenic sediment fingerprint of glacial sediment input. We seek to link relative changes in glacigenic input to past ice margin positions, using remote sensing constraints on bedrock transitions or sub-glacial topographic divides and basins. We find evidence of a glacial lake outburst flood observed in both records at ~10 ka BP, seemingly marking the onset of deglaciation and highlighting the swift response of the ice cap to Early Holocene warming. In light of rapid on-going and predicted warming, similar events may occur in the near future. However, grain size and geochemical data also reveal a weakened yet present glacial signal throughout the Early and Mid-Holocene. We note that the ice cap appears to have reached its Late Holocene maximum long before the Little Ice Age. By the Late Holocene, the progressing intensity of the glacial signal is accompanied by regular mm-scale micro-laminations thus recording glacier-climate change on human-relevant (decadal-centennial) timescales.

Reconstructing Retreat Dynamics of the Last Irish Ice Sheet Using Proglacial Lake Sediments

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Understanding the rate and pattern of current ice sheet deglaciation relies on long-term records of Quaternary ice sheet behaviour. This study investigates such a record in the form of glaciolacustrine sediments preserved from the retreat and breakup of the Irish Ice Sheet (IIS) during the Last Glacial Termination (LGT, c.21-14 ka) within the Irish Midlands.

Existing reconstructions of the IIS are based on geomorphological mapping of landforms, which are inherently discontinuous in their distribution and preservation. A more continuous archive can be found in proglacial lake sediment records. These lakes are sinks for glacially-derived meltwater and sediment, and enable continuous, spatially-integrated reconstructions of glacial and foreland environmental change, including annually or seasonally-resolved (varved) records. Sequences of laminated, varved, proglacial lake sediments from Palaeo-lake Riada are well-preserved in the Irish Midlands and provide valuable insights into IIS behaviour and lake sedimentation.

We present a new high-resolution analysis of laminated glacial lake sediments from Co. Offaly, close to IIS marginal landforms (moraines and eskers). A suite of physical and chemical analyses (including ITRAX μ-XRF, grain size, and thin section micromorphology) is used to reconstruct sediment and meltwater inputs and implications for ice sheet dynamics of the IIS during the LGT. The results and methodologies of this approach are explored here, with a focus on high resolution micromorphological assessment of laminations and how these facilitate palaeo-environmental reconstruction. These reconstructions are then used to provide context and relative chronologies to existing models of IIS retreat across the Irish Midlands.

This study demonstrates the value of lacustrine sediments to enhance and provide chronological context to existing ice sheet retreat models. Additionally, we demonstrate the utility of glaciolacustrine sediments to provide insights how into retreat patterns and behaviour of ice sheets during periods of climate amelioration, applicable to current and future dynamics of existing ice sheets.

Clasts in a subaquatic debrite – unifying results based on different methods

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The properties of clasts contained in debrites (debris-flow deposits) provide information on the sedimentological history of a sediment. These include: clast lithology, morphology (form, roundness), clast fabric, and in the case of soft-sediment clasts (SSC) – their internal structure. Here we concern on clasts in subaqueous debris flows. The study site is located at a coastal bluff of the Baltic Sea in the northern Poland, at Rzucewo village. Analyzed debrites were resulted from cohesive flows on a subaqueous fan, in a glaciolacustrine basin, probably during the decay of MIS 3 ice-sheet. The debrites contain both lithic clasts and SSC. The cross-section of the fan along the palaeotransport direction is exposed in the site, what with the richness of sedimentary record gives the possibility of research using various methods. Previous works enabled: (1) the reconstruction of triggers responsible for debris-flow generating, (2) the recognition of the diversity of SSC, (3) tracing the types of deformations formed as a result of debrite deposition, (4) the reconstruction of debris-flow directions. Recently, the morphology evolution of lithic clasts transported in a debris flow has been studied. The aim of the latest research is to investigate the features of debrites using computed microtomography (μCT) and thin sections (TS) analysis. Use of μCT enables 3D analysis of SSC and millimetre-size lithic clasts, while TS analysis gives insights into properties of debrite matrix. Combining traditional methods, mainly based on field works, with μCT and TS analysis led to a comprehensive recognition of debrite features and inference about the processes occurring in a debris flow.

Session 170: Biotic markers and measures of biodiversity of Holocene environmental change

Early Holocene vegetation development on islands of proglacial Lake Ojibway in northwestern Québec

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At the beginning of the Holocene, the Laurentide Ice Sheet was progressively melting and liberating eastern Canadian landscapes. Meltwater accumulated at the glacier front, forming the proglacial Lake Ojibway, which covered western Québec and eastern Ontario for approximately 2,000 years before flushing into James Bay around 8,200 years ago. Paleoecological vegetation dynamics reconstructions of sites covered by Lake Ojibway showed that spruce forests were established from the onset, whereas sites south of the southern extent of Lake Ojibway first went through a steppe period before being afforested. One possible explanation for this rapid postglacial forest establishment in western Québec is that islands present on Lake Ojibway (paleo-islands) were colonized by forests before the drainage of the proglacial lake, hence acting as migration outposts. However, this hypothesis had not yet been tested with empirical data. We studied sediments from two small lakes located on paleo-islands (current hilltops) of Lake Ojibway to reconstruct vegetation development and diversity at the local (macro-remains) and regional (pollen) scales. Afforestation occurred between 9,900 and 9,600 years before present on the paleo-islands and was followed by a transition from open woodlands to denser forests around 9,200 years ago. *Pinus banksiana*, *Picea mariana* and *Betula papyrifera* were thus established on the islands almost 1,000 years before the drainage of Lake Ojibway. We also used diversity indicators and charcoal particles counting to better understand and characterize the vegetation and fire dynamics. Diversity indicators showed opposite trends for macro-remains and pollen, indicating local diversification and regional homogenization of the vegetation, supporting the boreal-mixed wood establishment around 9,200 years ago. Charcoal particles combined with the Charcoal Size Distribution (CSD) method reveal that local fires occurred on the paleo-islands and seemed to trigger the vegetation diversification and densification observed. Our results suggested a high magnitude local fire could trigger the vegetation diversification during the colonization process. We also provided strong empirical evidence for boreal mixed wood forest early establishment on paleo-islands outposts, which likely fostered lowlands plant colonization following Lake Ojibway drainage.

Patterns and drivers of abrupt changes in mesic tree populations at Story Lake Indiana

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Over the last 8,000 years, populations of mesic tree species in the Great Lakes region have experienced large fluctuations in abundance, with taxa such as *Fagus grandifolia* (American beech) and *Tsuga canadensis* (eastern hemlock) often undergoing multiple collapses. These declines are well documented by fossil pollen records, but their synchronicity and drivers are not well understood, with hypothesized causes including drought, fire, density-dependent interspecific competition, or some combination of these extrinsic and intrinsic processes. For the Holocene-ACES project (Abrupt Change in Ecological Systems), we are collecting a series of new lake sediment records with multi-proxy indicators of past vegetation (pollen), drought (lake levels and delta C 13 from pollen grains), and fire (charcoal) records to understand the spatiotemporal patterns and drivers of tree population fluctuations. Here we show results from a 9 ka-to-present lake sediment record from Story Lake in northern Indiana, anchored by 15 radiocarbon dates, that shows at least two abrupt expansions of beech. The initial expansion of beech occurred at 6.9 ka, immediately after a dry period based on the lake level reconstruction of nearby Lake Lavine, MI. The second rapid rise of beech at 2.6 ka is associated with low plant water stress (low delta C 13 of pollen grains) and declining intensity of fire regime (decreased charcoal accumulation rates). The pattern and timing of beech variations at Story Lake differs substantially from other nearby well-dated records of beech declines, suggesting that collapses of beech may have been highly localized. These localized dynamics may indicate that the past ecotone between mesic beech forests and oak savanna in northern Indiana and southern Michigan was highly patchy and subject to locally governed rapid shifts in ecosystem state.

Temporal dynamics of invertebrate community assembly in modern Lake Victoria

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Preserved assemblages of invertebrate remains in the sediments of large lakes reveal centennial to millennial scale variations of community composition and environmental conditions. Such long-term records are rarely available from tropical lakes, including the largest tropical lake in the world, Lake Victoria. Here, we examine chitinous remains of larval Dipterans (Chironomidae and Chaoboridae) and Cladocera found in a new sediment core of Lake Victoria to quantify changes in the invertebrate assemblage from the Lateglacial period throughout the Holocene to the present (~13,700 cal yr BP to present). Lake Victoria has been a dynamic ecosystem with significant environmental variations, such as water level changes, biogeochemistry, and fish community composition, since the lake refilled ~15,000 cal yr BP. We detected three major changes in the assemblage of invertebrate taxa throughout the lake ontogeny. First, prior to the occurrence of cladocerans in the community, Chaoboridae and Chironomidae increased in abundance and sustained higher values from ~6,000-3,000 cal yr BP, which coincided with proxy data indicative of high diatom production towards the end of the African Humid Period. Second, starting ~5,000 cal yr BP, *Alona* spp., a predominantly littoral cladoceran, became established in the invertebrate community and persisted throughout the late Holocene to the present. Third, following the arrival of both *Chydorus* spp. and *Bosmina longirostris* around 2,000 cal yr BP, the community gradually shifted toward an increasing dominance of *B. longirostris*, typically a more pelagic cladoceran. This study provides the first multi-millennial record of sedimentary invertebrate remains in Lake Victoria and contributes valuable insight into the temporal sequence and dynamics of past invertebrate communities in response to ecosystem changes and climate variability.

Reconstructing the long-term dynamics and functioning of floodplain ecosystems through a multi-proxy and multi-site analysis

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Rivers and alluvial floodplains are dynamic environments, shaped by millennia of natural and anthropogenic induced changes. During the Early and Middle Holocene, most Northwestern European floodplains were stable environments, mainly influenced by natural forces, resulting in low-energy multichannel rivers in swampy floodplains. During the Late Holocene, forest clearances for agricultural purposes resulted in increased soil erosion rates and the burial of the Early- and Middle Holocene peat deposits under thick layers of sediment, transforming these environments into single channel meandering rivers with overbank deposits. While the general framework of this transformation is well-established, many uncertainties still exist given the strong spatiotemporal variability of this change in geoecohydrology. In this study, we reconstruct the Holocene geoecohydrological changes for five river catchments in northeastern Belgium through a multi-proxy approach. A combination of cluster analysis, ordination and Ellenberg indicator values (EIVs) is applied to a large palaeobotanical dataset to enable an objective identification and explanation of patterns.

The vegetation history of the studied floodplains is marked by an alternation between *Alnus* and Cyperaceae domination, which seems strongly controlled by moisture. While *Alnus* is locally present from at least ca. 11,200 cal. BP in northeastern Belgium – supporting the hypothesis of a western European refugium – its expansion happens in most cases several millennia later. The Early Holocene regional forest expansion resulted in a gradual decrease of water and sediment to the valleys, and *Alnus* started to dominate the local floodplain vegetation once the peat became sufficiently dry. The opposite can be observed in the Late Holocene, when the relatively dry *Alnus*-dominated floodplains transform back to more open and wet environments, linked to regional deforestation and the consequent renewed increase in water and sediment delivery from hillslopes to river valleys. These transformations are, however, highly heterogeneous in timing between and within (sub)catchments, suggesting that local factors including soil type and topography play an important role in the sensitivity to these changes in land cover. Such insights into the long-term dynamics of floodplain ecosystems, and their responses and sensitivity to changes in driving forces are of great importance in the development of sustainable management plans.

Climate change and human activity drive vegetation change during the last eight millennia in the Xistral Mountains of NW Iberia

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An 8500-year record of high-resolution pollen, non-pollen palynomorph, microscopic charcoal and selected geochemical data (Ti, Zr and Pb) are presented from an ombrotrophic mire from the Serra do Xistral, Galicia, North-West Iberia. The results suggest that vegetation changes over the last eight millennia are primarily the result of human disturbance, fire and climate change. Climate and fire were the main factors influencing vegetation development during the early to mid-Holocene, including a short-lived decline in forest cover c. 8.2 ka. Changes associated with the 4.2 and 2.8 cal. BP events are less well defined. Human impact on vegetation became more pronounced by the late Holocene with major periods of forest disturbance from c. 3100 cal BP onwards: during the end of Metal Ages, Roman period and culminating in the permanent decline of deciduous forests in the post-Roman period, as agriculture and metallurgy intensified, leading to the creation of a cultural landscape. Climate change appears to become less influential during the Late Holocene as human activity dominates.

Holocene interactions between paleoecology and fishing practices in sub-Antarctic South America

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Concerns about the conservation and management of marine ecosystems are currently growing. The Patagonian coastal ecosystems are one of the least intervened environmental regions worldwide, representing a real "hotspot" of biodiversity of great value and importance for its sustainability. In this paper, past fishery resources in the Strait of Magellan (MS) and Beagle Channel (BC) are evaluated by temporal and spatial variations in fish diversity and productivity based on archaeological, ichthyoarchaeological, and paleoecological data. Both regions present 7500 years of human history, and they are located in different insular and continental coastal environments, representing the environmental heterogeneity.
The ichthyoarchaeological assemblages of 14 from MS sites and of 17 from BC sites are analyzed in this paper. Results reveal spatial and temporal variations in fishing practices, which are closely related to the mobility of canoe groups, the development of fishing technologies, and the use of the diverse microenvironments. The ichthyoarchaeological assemblages from the mid to late Holocene and the encompassed space between MS and BC show that fishing patterns are period- and location-dependent. Between 7500 - 5000 years BP S. australis and M. magellanicus predominate in BC, while a slightly more diversified pattern of exploitation was observed in MS, including demersal fishes and shore environments. During 4000 - 2500 years BP there is a significant change in fishing preference MS, with both regions registering an exploitation focused of resources from environments located deeper and further offshore (demersal benthic), such as Salilota australis. There is less archaeological information available in the BC for this period, but the ichthyoarchaeological assemblages show a similar pattern in the exploitation of deep-sea species from an increase in the representation of Merluccius australis. Finally between –2500-100 years BP both the MS and BP there is a significant change, the rockfish and pelagic fish dominate the assemblages.
Together with regional paleoecological data, our results indicate that environmental changes during the late and mid Holocene affected fish taxa representations in the archaeological assemblages, and therefore the fishing practices used by the marine hunter-gatherer groups that inhabited the region for more than 7500 years.
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Palynological determinations of species richness and spread from southern Greenland around the time of the Norse landnám

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The Norse colonisation of the North Atlantic islands, beginning c. AD 800, resulted in the dispersal of a suite of 'alien' flora and fauna (anthropochores) to remote high-latitude environments with relatively simple biogeographies. Equally important were the opportunities created by human settlement for the expansion of a wider range of native species (apophytes). In many instances, the locations that were settled by the Norse may been viewed as 'natural laboratories' in which to study the impacts of anthropogenic activity on ecosystems and environments, given the western North Atlantic islands (i.e. Faroe Islands, Iceland and Greenland) were largely unoccupied prior to the arrival of the Norse. This paper will demonstrate the value of palynological evidence in investigating changes in the diversity and complexity of vegetation in Greenland as a result of the Norse landnám (Old Norse: 'land-taking', c. AD 1000), an event which phytogeographers have speculated could have resulted in the introduction of up to 5% of the region's modern flora. With a focus upon the area of southern Greenland known as the Eastern Settlement (Eystribyggð), this analysis is made possible through synthesis of data from a network of pollen sites, each typically featuring high-temporal resolution sampling, supported by precise age-depth models and estimates of species richness (rarefaction) and spread. We will also consider the 'legacy effects' of land abandonment – from c. AD 1400 forwards – on the region's vegetation. The period leading into, through, and after settlement in Greenland is of added interest and importance to studies of biodiversity given its broad temporal correspondence with the shift from the warmer conditions associated with the 'Medieval Climatic Optimum' (MCO) to the colder 'Little Ice Age' (LIA).

Hitchhikers, maritime routes and biogeographic change

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Movement of people and the spread of farming has also to do with the spread of insects and biogeographic change. This process involved different pathways including both maritime and riverine transport, with insects passively ferried in cargo, dunnage and ballast. Some, as human lice and other ectoparasites of humans and domestic animals, also travelled on their hosts, while others, as wood borers, pests of crops and dung beetles would hitch a ride. This paper will provide an overview of introductions of insects using evidence from shipwrecks and key ports, examining change overtime in terms of range and number of species, differing maritime routes and change over time. The data go back at least 2600 years ago and provide us with some understanding of pathways for invasive species. Most of the insect data come from the medieval and post medieval period, when ships became larger and less likely to be thoroughly cleared out between voyages, allowing beetles and flies to become residents in ballast and dunnage. At that point, various species, taking advantage of the foul conditions in ships' holds, started spreading geographically, following the routes of colonisers and traders and providing interesting information about itineraries, goods traded and conditions on board. A number of post-medieval references provide some information, from mentions of cockroaches on a galleon off the Azores, to the complaints of weevil-infested bread from James Cook's crew in the late eighteenth century. Our insect data from two shipwrecks from the Azores include the first and early records of now cosmopolitan species of flies and cockroaches and the work sheds light on their spread through maritime trade and the importance of ports of call. The fossil insect record from wrecks and other assemblages from ports and relevant contexts, show the process of accidental imports, which are often strongly associated with exchange networks and give an alternative record for ecological imperialism through maritime trade.

Session 173: Palaeoclimate records from the Southern Hemisphere

Long-distance transported pollen record from sub-Antarctic Kerguelen shows Southern Hemisphere Westerly Wind dynamics during the Holocene

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The Southern Hemisphere Westerly Winds (SHW) play a major role in the regulation of the global climate. Through wind driven upwelling, the SHW affect sequestration of atmospheric CO_2 and heat uptake by the Southern Ocean. Changes in the position and strength of the SHW core belt can greatly affect the intensity of these processes through invigoration of the Antarctic Circumpolar Current. Understanding the SHW's natural variability is crucial to comprehend the wind driven component of the carbon cycle. Recent intensification and southward movement of the SHW core belt has been inferred, but long-term changes in its behavior remain largely unconstrained. We reconstruct changes in the SHW through a tested method with unique application: using the accumulation rate of long-distance transported (LDT) pollen grains and charcoal from the main continental landmass of southern Africa to the sub-Antarctic island of Kerguelen. Unlike the vast majority of previous LDT pollen studies where pollen fluxes are interpreted as a measure of SHW strength, the position of Kerguelen relative to Africa allows us to use our data to infer changes in zonal position of the SHW core belt. In addition, a combination of palynological and stratigraphic evidence is used to reconstruct local Holocene climate. Our results show that there have been substantial changes in local and regional climate variability during the Holocene. We infer a dynamic Early Holocene and relatively stable climatic conditions over Kerguelen during the Mid- to Late Holocene, coinciding with a tipping point in the SHW's latitudinal position: from a more southward to equatorward position around 8,5 ka BP. These results are supported by other paleorecords from the region and suggest large-scale changes in SHW behavior on millennial to centennial timescales.

The ITCZ variability during the last three millennia in Northeastern Brazil and related impacts on human population

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Changes in tropical precipitation over the last millennia have usually been associated with latitudinal displacements of the Intertropical Convergence Zone (ITCZ), but recent studies provided evidence that contraction/expansion of the rainbelt have contributed to precipitation variability. In South America, the scarcity of paleoclimate records in the northern portion of the continent prevents a clear understanding of ITCZ changes in the region. In order to fill this gap, our study presents a reconstruction of paleo-precipitation for the last 3000 years from Northeast Brazil (NEB) based on oxygen isotopes in speleothems. NEB receives most of its precipitation from the ITCZ when the core of convection is located in its southernmost position. The association between our oxygen isotopes record with paleo-precipitation records located at northern position of ITCZ indicates that the range of seasonal migration and contraction/expansion of the ITCZ was not symmetrical over the equator. During the period corresponding to the Medieval Climate Anomaly (MCA), our record shows an abrupt transition from wet to dry conditions, which persisted until the onset of the period corresponding to the Little Ice Age (LIA), This interval is characterized as the longest dry period in the last 3000 years in NEB. Our stalagmite documents abrupt and strong drought events occurring during the LIA (~1500 – 1850 CE) that correspond with historical droughts documented by the Portuguese colonialists. These droughts recorded by the NEB stalagmite indicate that these events were able to affect the population, karst system and environment of NEB. The correspondence of geological and historical records demonstrates how important speleothem science is for this region to document past climate and occurrence of extreme events that have the potential to affect human life.

Large-scale reorganisation of atmospheric circulation for the late Holocene derived from a 7.2 ka Altiplano peatland record (Cerro Tuzgle, NW Argentina)

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High-elevation cushion peatlands are promising archives for paleoenvironmental studies in their extreme habitat of the Central Andean highlands between 4000 and 4800 m a.s.l. We present the environmental and climatic history for the last 7200 years of Cerro Tuzgle peatland (CTP), located in the dry Puna of NW Argentina.
The stable isotope composition of bulk material and cellulose ($\delta^{18}O$, $\delta^{13}C$, $\delta^{15}N$) of the dominant cushion-forming species *Oxychloe andina* (Juncaceae) and *Zameioscirpus muticus* (Cyperaceae) were investigated. We further applied a multiproxy approach with XRF scanning and bulk geochemistry. Pollen assemblages give an insight into substantial environmental changes on a regional scale.
The results reflect prominent late Holocene climate anomalies and provide evidence that in situ moisture changes were consistently coupled to temporal changes in the match to South American Summer Monsoon (SASM) reconstructions during the last 2900 cal yr BP.
The prominent feature of the entire record is a distinct and lasting transition centred around 3100 cal yr BP characterized by declining minerogenic content, increasing organic carbon content, rising stable carbon isotope values of organic matter and cellulose, and increasing stable oxygen isotope values of cellulose. We interpret this specific proxy pattern as a hydroclimatic transition towards less arid conditions at the CTP after 3100 cal yr BP. Moisture supply during a more arid middle Holocene was provided by isotopically depleted precipitation, while moisture supply after the transition originated from isotopically enriched SASM summer precipitation. Concurrent hydroclimatic changes in the SHW winter precipitation regime south of the South American subtropical dry zone (SASDZ) are documented in a distinct lake level rise of Laguna Aculeo (33˚50´S) around 3200 cal yr BP. These coinciding hydrological changes of the SASM and the Southern Hemisphere Westerlies precipitation regimes indicate larger scale reorganisations of atmospheric circulation components, potentially connected to major modulations of the SASDZ. Thus, our CTP record sheds light on the middle to late Holocene development of the SASM at its southern limit and corroborates connections between the tropical and extratropical hydroclimate of South America.

Interaction of tributary alluvial fan and fluvial sediments during the Late Pleistocene - Holocene transition in the arid southern Central Andes.

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New mapping and luminescence geochronology of fluvial and alluvial fan deposits from the arid southern Central Andes of Chile were used to infer Pleistocene-Holocene paleoclimate for this high relief region. During this period, alluvial fans descending from tributary catchments into major river valleys encroached on fluvial deposition, creating a record of interbedded fluvial-alluvial fan deposition. In many places, alluvial fans obstructed river flow and generated extensive river damming, with associated lacustrine deposition. In addition to geochronology, the sedimentology and pedology of several sets of alluvial fan deposits were also characterized. The oldest sequence of fan deposition (~40 ka) appears as isolated deposits on hillslopes and is highly eroded. Two regionally distributed, massive (25-100 m thick) fan sequences are dated to 14-9 ka and post ~5 ka. Deposition of the 14-9 ka fans in catchments sourced from both high and intermediate elevations suggests a common factor in generating these fans, which we interpret as linked to a regional precipitation increase derived from Pacific moisture sources. An intermediate sequence of fan deposition occurred ~8.2 ka in some outlets sourced from high elevation catchments. The occurrence of these fans during the most arid period of the Holocene in the southern Central Andes suggests an easterly moisture source for the precipitation events that generated the fans. The post-5 ka fans can be associated with a relative increase in precipitation during the late Holocene, previously documented at these latitudes in the southern Central Andes. The largest fans associated with a Late Pleistocene precipitation increase were probably driven by a northward excursion of the Westerlies. The 8.2 ka event is relevant to hazards analysis today and in the near future with predominance of arid conditions.

Developing a hydrological transfer function for montane peatlands in the tropical South Pacific

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Background: The South Pacific Convergence Zone (SPCZ) exerts a strong influence on precipitation patterns across the central South Pacific. A small displacement in the position of the SPCZ causes drastic changes to the hydroclimate conditions and the frequency of extreme weather events (such as prolonged droughts, floods, tropical cyclones), experienced by vulnerable tropical island nations in the region. Palaeoclimate reconstructions of ocean temperature, salinity and rainfall derived from speleothem, coral, lake and swamp archives have advanced our long-term understanding of the SPCZ in the southwest Pacific. However, palaeohydrological records spanning the full Holocene are rare. This is due to a lack of conventional sites typically used for millennial-scale proxy reconstructions, which has limited efforts to extend observational rainfall and tropical cyclone data sets. While longer-term changes in tropical vegetation and human activity have been recorded in sediment archives, proxies specifically targeting centennial-scale hydrological shifts are needed to further hone of understanding of precipitation fluctuations governed by the SPCZ in the tropical southwest South Pacific.

Our project: Montane peatlands in the humid highlands of Taveuni (Fiji) and Futuna (Wallis and Futuna) offer rare palaeoclimate archives in the southwest Pacific region. We investigate the potential of testate amoebae (a group of single celled free-living protozoa) to infer a Holocene hydrological signal from the two peatland complexes. Over the last two decades, testate amoebae have been mainly used to reconstruct changes in hydrological conditions in peatlands, typically expressed as water table depth. In 2022, surface soil and vegetation samples were collected, and abiotic (depth to water table, pH and conductivity) variables were recorded, from distinct habitats in the Lake Tagimaucia peatland in Fiji, and a peatland on Mt Puke in Futuna. Micro-topographical gradients (pools to hummocks) were targeted to capture a hydrological range. In the first phase of this study, we examine the ecology of contemporary testate amoebae and their relationship with key abiotic variables and test the hypothesis that their distribution is primarily controlled by hydrological conditions. We will then build two separate transfer functions to reconstruct the dominant controls on testate amoebae assemblages from each peatland complex.

Temperature and hydroclimate reconstructions over the past 16 kyr from Lake Llaviucu, Ecuador

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Decades of research have produced a coherent picture of global temperature change since the Last Glacial Maximum, with global warming during the last glacial termination punctuated by millennial-scale cool intervals such as the Younger Dryas (YD) and Antarctic Cold Reversal (ACR). However, quantitative reconstructions of temperature are geographically biased toward the oceans and northern latitudes, limiting our understanding of global climate processes and the global footprint of millennial-scale cool events such as the YD and ACR. To better understand the impacts of 'northern' vs. 'southern' modes of temperature changes in the southern tropics, we examine branched glycerol dialkyl glycerol tetraether and leaf wax hydrogen isotopes in a 12 m sediment core from Lake Llaviucu, Ecuador, to develop high-resolution temperature and hydroclimate records for the past ~16000 years. Our δ^2H record suggests the tropical Andes experienced a transition from a relatively wet to a dry climate from ~16 to 12 ka, a dry early Holocene, and a long-term trend toward wetter conditions in the late Holocene, consistent with seasonal insolation forcing of the South American Summer Monsoon. This hydroclimate variability agrees with the stalagmite oxygen isotope records from a nearby cave, validating the age model of our lake sediment core. Our reconstruction indicates ~4 °C warming during the glacial termination, punctuated by a ~1.5 °C cold interval that is concurrent with the ACR. This points to an important influence of meltwater forcing and sea surface temperatures over the South Hemisphere on tropical Andean temperatures during the deglaciation. During the Holocene, our temperature reconstruction is very stable, then shows a gradual warming trend since ~6000 yr BP, which was likely controlled by increasing atmospheric CO_2. Unlike other parts of the tropics, we do not observe an early to mid-Holocene thermal maximum, suggesting a limited influence of feedbacks amplifying northern hemisphere summer insolation in our study region. Our results highlight the complexity of this region and the need to acquire more quantitative temperature records from the southern tropics.

Middle to Late Holocene environmental dynamics of the subtropical Andes (32°-36°S)

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The subtropical Andes (32°-36°S) are one of those areas in the world that has been experimenting a strong trend to more arid conditions as the result of increased temperatures and a reduction in (winter) precipitation due to the ongoing climate change. Precipitation in the high Andes, related to the Southern Westerlies, is the source of water for central Chile and Argentina becoming therefore a key resource in socio-environmental terms. The scarce long-term records in the Andes located in the western lowlands point out that this region experimented widespread and extreme arid conditions during the Middle Holocene. Hence, studying the high Andean environments response to such conditions in the past would provide some clues to face the future scenarios in this region. Thus, this work aims to reconstruct the paleoenvironmental dynamics of the subtropical Andes (32°-36°S) at centennial/sub-centennial scale by presenting the pollen record of Laguna Corazón (LCO; 35,14°S-70,21°W) and other high Andean records spanning the Middle to Late Holocene. Naked-eye description, RX radiographs, Loss on Ignition, and pollen analysis were performed on the 2.4-meter long sediment core of LCO dating back 5400 yrs BP. The sedimentary record is mostly composed of dark-brown laminated silts and presents a volcanic ash layer at 21-24cm depth that according to the chronological control could be attributed to the 1932 Quizapu eruption. The LCO record reflects the development of a grass steppe with a millennial scale drier-than-present phase between 5400-3000 yrs BP, more humid conditions than present between 2700-1100 cal yrs BP followed by a decrease in moisture up to 300 cal yrs BP when similar than present conditions established but under a high environmental variability. Other high Andean lake records at 32°, 33° and 36°S point out drier-than-present conditions during the Middle Holocene even the peak/amelioration of such conditions is asynchronous probably related to their latitudinal/longitudinal position regarding the precipitation source.
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The Late Quaternary environmental history of the Kalkkop palaeolake: a unique terrestrial record from the Nama-Karoo Desert, South Africa

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The contemporary Nama-Karoo region is defined by its semi-arid environment which hosts a desert and xeric shrubland matrix. However, a meteorite impact in the Eastern Cape of South Africa led to the formation of a deep lake system during the Quaternary. A core extracted from the profundal zone penetrated 89 m of lacustrine deposits, achieving ~80% sediment recoverability. A basal sample from the lacustrine sediments date the lake's origins to ~250 ± 50 ka based on U–Th, while a near surface sample suggests lake extinction occurred at ~18 cal. ka. The core is dominated by fine laminations, with some massive deposits. The grey scale index revealed several major cycles within the data potentially alluding to key climatic shifts. A multiproxy approach, which included spectrophotometry, magnetic susceptibility, CNS elemental analysis, grain size analysis and diatom analysis, was undertaken at an approximately 16 cm resolution. Based on these analyses, three main phases of development could be ascertained, namely Z1: 8735 –7938, Z2: 7904 –1881, Z3: 1866 –0 cm. The I-band index, which isolates the [660, 670 nm] reflectance trough values as produced by Chlorophyll-a and its diagenetic products, revealed low, high, and moderate periods of primary productivity, respectively. Diatom preservation potential is greatest in the lower 30 m of the core and is dominated by a high representation of pioneer species, suggesting some degree of environmental variability but with permanent, close to neutral to slightly alkaline, open water conditions. Future research will focus on lipid biomarkers and trace elemental analyses but primarily on a more detailed U-Th chronology, annual layer counting and the generation of a detailed age model. The implications of this new palaeoclimate archive presented here, plus its future age model, are significant given the site's depositional period and its proximity to the rich archaeological record of early modern human behaviour on the adjacent southern Cape coast.

A comparison of pollen and macrofossil-based reconstructions of vegetation and climate: Case studies from Southeastern Australia

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Despite its widespread use in palaeoecology, pollen-based reconstructions are limited by coarse taxonomic resolution. Pollen of narrow-range species that might be used as ecological indicators, for example, can be difficult or impossible to distinguish from the pollen of geographically widespread, and therefore less informative, taxa. Plant macrofossils, by contrast, are routinely identified to species level, and a majority of the species present in Southeast Australia during the late Quaternary still exist today. These improvements to the taxonomic precision of palaeobotanical records allow for the use of bioclimatic niche models to quantitatively reconstruct palaeoclimate, based on fossil species' modern day climatic niches. Combining these two proxies, we are able to produce a more nuanced interpretation of late-Quaternary vegetation and climate.

We sampled for pollen, plant and insect macrofossils at multiple sites across Southeast Australia. For each, we produced detailed pollen records which indicate regional-scale vegetation change. In addition, select macrofossils were identified to higher taxonomic resolution, and based on those species' modern-day bioclimatic profiles, we are able to quantitatively reconstruct the climate at the time of deposition. Radiocarbon and Optically-Stimulated Luminescence dating confirm that these sites fall within the last glacial period; one of which is a continuous record from the Last Glacial Maximum (LGM) to present, and which represents a rare mainland Australian refugium of the cool-temperate rainforest tree *Nothofagus cunninghamii*.

By examining both pollen and macrofossils, we are able to provide precise new insights into the composition of Southeast Australian communities and climate. These data will also illuminate the historical biogeography of individual species and provide crucial insights into the degree of sensitivity of Australian plant taxa to changes in climate in general.

Late glacial climate evolution in the Patagonian Andes from glacier modelling

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Numerical glacier models applied to moraine chronologies provide an opportunity to quantify past climate change. Here we apply a two-dimensional coupled mass balance – ice flow model to well-dated moraine sequences of two Patagonian glaciers at 44 and 47°S to reconstruct the local temperatures during both the Antarctic Cold Reversal (14.7–13 ka) and the Younger Dryas (12.9–11 ka). Modelled temperature anomalies during the Antarctic Cold Reversal are 2.6 ± 0.4 °C at 44°S, and 2.9 ± 0.6 °C at 47°S. At both locations this cold event is followed by temperature increases of +0.6 – 0.7 °C or precipitation reductions of c. 20% to drive glacier retreat to moraines deposited during Younger Dryas time. The consistent climatic anomalies between these two latitudes suggest this region of Patagonia was responding to a common climatic event. Further, the late-glacial temperature anomalies found here compare well to those determined by similar glacier modelling techniques in New Zealand, at 43–44° S. These results support a trans-Pacific response throughout the southern mid to high latitudes (43–47° S) during the ACR that is best explained by a northward expansion of the south westerly winds.

Flipping the wet-dry dichotomy: moist glacial and dry interglacial climates across the Southern Hemisphere subtropics

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Late Pleistocene glacial periods have been widely characterised by low vegetation biomass, and routinely interpreted as indicating climates drier than today, ignoring the effects of low atmospheric CO_2 on plant growth. Here, we measure the timing of speleothem growth in the southern hemisphere subtropics, which today mostly has a negative annual moisture balance, in order to develop a record of climatic moisture availability that is independent of vegetation. Our records from caves in southern South and Western Australia reveal that, over the past ~350 ka, high moisture availability was largely confined to glacial periods, while warm interglacial periods supported little speleothem growth. This moist-glacial response is consistent across the Southern Hemisphere, implying that high subtropical moisture availability is primarily driven by reduced evaporation under cool glacial temperatures. Our findings suggest that widespread interpretation of Southern Hemisphere subtropical glacial climates as environmentally difficult times for plant, animals and people, should be reconsidered.

Tracking an anomaly: a MIS 6 warming event in Tasmania, Australia.

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The Earth system is rapidly changing in response to anthropogenic climate change. Reliable modelling and climate predictions, which depend upon high-resolution and continuous paleoclimatic reconstructions, are crucial for future environmental management. In Australia, and indeed the southern hemisphere, continuous terrestrial records that stretch into the Pleistocene are extremely rare. The Darwin Crater of western Tasmania is an exception, offering ~70m of lacustrine sediment and ~800,000 years of paleoclimatic history. Darwin Crater therefore provides a unique opportunity to analyse deep-time southern hemisphere climate dynamics.

Numerous marine cores surrounding Tasmania suggest an anomalous oceanic warming during Marine Isotope Stage (MIS) 6, yet the limited data makes it difficult to draw conclusions. Analysis of the Darwin Crater core for this project has revealed a decoupling of Tasmanian and Antarctic climate during the same period (MIS 6). This anomaly raises questions about ocean-atmosphere teleconnections in this regionclimate change, as Tasmanian climate is generally very faithful to trends in Antarctic climate.

This project investigated the pollen record from across MIS 6 in the Darwin Crater terrestrial record and the FR1/94-GC3 marine record (offshore Eastern Tasmania), identifying the anomaly of interest. The spatial extent of this anomaly was then explored, after which a potential mechanism influencing this anomalous warming period in the marine and terrestrial records across Tasmania was suggested. By investigating both the marine and terrestrial records during MIS 6, this research has added critical information to the under-documented southern hemisphere palaeoclimate record and the globally-significant southern ocean.

The Mid-Pleistocene Transition in the Southwest Pacific

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The Mid-Pleistocene Transition (MPT) in global climate is evident from a shift in the frequency and characteristics of glacial-interglacial cycles, from small amplitude symmetrical 41 kyr cycles to large amplitude asymmetrical 100 kyr cycles starting around 1.2 Ma. The reason for this shift is highly debated as there is no change in the long-term pattern of insolation at this time. There are several hypotheses for this transition including (and not mutually exclusive); enhanced CO_2 removal from the atmosphere; coeval timing of ice sheet expanse in the northern and southern hemisphere, deep ocean cooling and reduced ventilation in the Southern Ocean; and intensification of the tropical Pacific Ocean/atmosphere circulation.

In this study we compiled existing data covering the last 1.2 Myrs with several new stable isotope records from marine cores from the Southwest Pacific Ocean. Previous work largely focussed on sea surface temperature (SST) changes as the MPT evolved. These studies found a large increase in the glacial/interglacial SST amplitude across the subtropical front. We have developed two new Tasman Sea marine stable isotope records from Lord Howe Rise (DSDP591A) and east of Tasmania (ODP1172). These data suggest there were broader changes in circulation in the Southwest Pacific across the MPT transition. These oceanographic circulation changes had an impact on the climate of the region as indicated by pollen evidence from the marine cores and other coastal and terrestrial evidence for climate change.

The marine data provides context for the Million Year Ice Core (MYIC) and Beyond EPICA Ice Core (BEIC) projects that is being drilled at Little Dome C in East Antarctica over the next few years to target the MPT transition.

South Pacific Antarctic Intermediate Water variability during the last deglacial atmospheric CO2 increases

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Antarctic Intermediate Water (AAIW) forms in the Southern Ocean and is currently one of the main sinks of atmospheric CO_2. During the last deglaciation (21,000-10,000 years before present), atmospheric CO_2 levels increased significantly during two specific time periods, the Early Deglaciation (~17.5-14.7 ka BP) and the Younger Dryas (~12 ka BP). Model simulations and data studies suggest that processes in the Southern Ocean were crucial in explaining these changes. Deep mixing and upwelling occurred during the deglaciation in the Southern Ocean, close to where AAIW is formed, leading to degassing of CO_2 formerly stored in the deep ocean. These processes may have influenced the composition of the newly formed AAIW, and hence its role in atmospheric CO_2 changes, but its variability and properties in the Pacific Ocean are still unclear. To fill this gap, we show over the last 30,000 years benthic foraminiferal carbon and oxygen isotopes, benthic Mg/Ca bottom water temperatures, salinity reconstructions and grain size analyses from deep sea Ocean Drilling Program (ODP) Site 1233 in the Southeast Pacific Ocean off Chile. Our bottom water temperatures show a ~4°C warming during deglaciation and salinity reconstructions indicate a freshening during the Early Deglaciation, however, there is no long-term trend from the Last Glacial until the Holocene. Benthic carbon isotopes show a clear negative anomaly (of ~1 ‰) during the Early Deglaciation and the Younger Dryas, synchronously with evidence of major upwelling in the Southern Ocean, major increase in atmospheric CO_2, and negative atmospheric carbon isotope values in Antarctic ice cores. We interpret these low $\delta^{13}C$ values as first direct evidence for the entrainment of low $\delta^{13}C$ into AAIW that most likely stem from upwelling of deep and old ocean water masses in the Southern Ocean. Our results hence support existing hypotheses that Circumpolar Deep Waters with low $\delta^{13}C$ formerly isolated from the atmosphere entrained into AAIW during the deglaciation with consequences for low latitude primary productivity and atmospheric CO_2 and contrast with previous studies from AAIW depths in the West Pacific or deeper water depths from the Southeast Pacific that described higher benthic $\delta^{13}C$ values.

The Southern Ocean's role in the global carbon cycle over the last 800 kyr constrained using reconstructions of the CO2 system

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The critical role of the Southern Ocean in controlling the Pleistocene atmospheric CO_2 oscillations is widely acknowledged. However, hindered by sampling difficulties surrounding Antarctica, the underlying mechanism and associated pathway of ocean-atmosphere CO_2 exchange in the Antarctic zone of the Southern Ocean remains mysterious. CO_2 exchange between the ocean and atmosphere is closely coupled with the pH and partial pressure of CO_2 (pCO_2) of surface seawater. Here, we present a new $\delta^{11}B$ record of *Neogloboquadrina pachyderma* from sediment core PS1506 (68.73°S, 5.85°W) that tracks the pH and surface pCO_2 of the Antarctic zone of the Southern Ocean over the last 8 glacial cycles. These data are complemented by benthic B/Ca and carbonate preservation indices; due to the location of this core on the continental margin of the eastern Weddell Sea, these data allow us to track the source CO_2 chemistry of the dense Antarctic waters that feed the ocean's lower overturing cell. From these data, we discover a tight relationship between seawater CO_2 chemistry and atmospheric CO_2, thereby highlighting the Southern Ocean's key control on glacial-interglacial CO_2 change. Considering the changes in carbonate preservation seen at this site, we also investigate the potential influence of dissolution on the shell chemistry of *N. pachyderma*. Together, our records provide direct geochemical evidence of changes in the Air-Sea CO_2 exchange of the Antarctic Zone of the Southern Ocean over multiple glacial cycles, and also contribute insights into the applications of foraminiferal $\delta^{11}B$ in paleoceanography.

Session 174: Tracing the impact of palaeoenvironmental changes in ancient DNA

Successful isolation of endogenous ancient DNA from subfossil Dryas octopetala leaves preserved in an ice cave

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Analysis of ancient DNA (aDNA) preserved in subfossil plant remains can provide deep insights into the evolutionary history and processes involved in the current genetic diversity of organisms. However, DNA preservation in ancient soft tissues is influenced by an array of biological, chemical, and physical processes, typically leading to very low amounts of DNA, which is invariably degraded to short fragments. Permafrost and ice caves often contain ancient plant remains and due to frozen conditions, which are optimal for DNA preservation, such fossils might be a rich source of aDNA.

Here, we focus on exceptionally well-preserved *Dryas octopetala* leaves (5,600–2,200 years old) stored in the Armeña A294 ice cave (Central Pyrenees, Spain). As a cold-adapted arctic-alpine dwarf shrub, *D. octopetala* expanded around the ice cave during the Neoglacial cooling period (ca. 4,600 years ago), where it still occurs. However, human-induced climate warming can reduce its occupancy range, leading to a decrease of genetic diversity. As a starting point to track genetic variation at high temporal resolution, we aimed to authenticate the endogenous DNA potentially preserved in the subfossil leaf remains.

DNA isolated from the subfossil *D. octopetala* leaves was incorporated into single-stranded libraries and sequenced on an Illumina platform. The results strongly indicate that the DNA we isolated contains endogenous ancient *D. octopetala* DNA. Assembled chloroplast sequences were nearly identical (99.91%) to a partial *D. octopetala* reference chloroplast genome sequence, and the chloroplast sequence reads showed all the key characteristics of aDNA: very short fragment size (mean read length between 54 and 70 bp); increased occurrence of purines before strand breaks; and increased frequency of cytosine-to-thymine misincorporations close to the ends of the DNA fragments. The endogenous DNA content of the samples was very low (≤ 1%). Thus, for a deep analysis of genetic variation, we will use a capture-based method to enrich the endogenous DNA component of the libraries, particularly functional nuclear genes. The sequence data will provide a baseline of genetic diversity before the onset of the human-induced climate change.

New insights into early human impact, animal domestication and landscape transformation in the Central Pyrenees (Spain) through sedaDNA analysis

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Current Global Change (GC) is proving to be unprecedented, showing nature’s vulnerability to both climate and environmental changes, particularly in key sensitive areas such as high mountain regions. To adapt and mitigate the impact of GC in the mountains, the compound effects of climate variability and human activities in these regions have to be disentangled. In this sense, tracing early human impacts in mountain environments is key to understand climate-human interactions and inform future climate scenarios.

This work is focused on the identification and characterization of anthropogenic indicators in the Central Pyrenees, an Iberian region highly sensitive to past climate changes and with a long record of human occupation. Despite numerous paleoenvironmental studies of this region, data are insufficient and lack consensus among interpretations to define the timing and role that humans played in shaping early Pyrenean landscapes.

Through the re-study of a new sediment core from Tramacastilla Lake (42°43’35“N, 0°22’04”W, 1682 m.a.s.l.), we aim to test two long-debated questions: 1) the timing of arrival and history of animal domestication in the Pyrenees; and 2) the impact that animal husbandry may have had on plant communities in the subalpine belt. In this contribution, we present innovative paleocological results, through the analysis of plant and animal sedimentary ancient DNA (*sed*aDNA) from 46 samples, that inform about the past ecological dynamics of plant and animal taxa.

Our results identify domestic animals (cows, sheep, goats) in the surroundings of Tramacastilla since ca. 6 ka BP, and a concurrent expansion of open vegetation landscapes that progressively increased from ca. 4 ka BP, consistent with pastoralism. In addition, our results show the existence of bovines since the onset of domesticate presence in the region, challenging the long-time assumed idea of ovines and caprines being the dominant domesticates in the Pyrenees. Our findings allow us to reconstruct not only human land-use through an abrupt landscape opening since the Early Neolithic in the southern Central Pyrenees, but also provide data to design current day conservation strategies that integrate the traditional management of landscapes in the mountains.

Lake sedimentary ancient DNA reveals ecosystem response to fire and climate on Kangaroo Island (Karti), Australia

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Increasingly hotter and drier climate combined with post-colonial changes in land management have led to more catastrophic fires across southern Australia in recent decades - threatening people and the environment. However, there is still a lot we don't understand about the complex interplay between climate, fire, ecosystems, and people - especially on longer timescales that pre-date British colonisation. Our study focuses on Kangaroo Island, where devastating bushfires decimated the island's unique ecosystems in 2019-2020. We used shotgun metagenomics of sedimentary ancient DNA (*sed*aDNA) to reconstruct the aquatic and terrestrial biodiversity within the green plants group (Viridiplantae) over the last ~ 7,000 years from the sediments of Lashmars Lagoon. We compared our *sed*aDNA record to a pollen record, charcoal-inferred fire history and geochemical proxies for catchment and climate processes to provide new insights into plant community responses to climate and fire. We found compositional changes statistically linked to fire history and climate change. Specifically, sediment calcite content (linked to drier climates) significantly explained changes in composition within the Viridiplantae. Statistical analysis further revealed that the major compositional change within the Viridiplantae, including a decrease in the Fabaceae family (which includes the genus *Acacia*), coincided with an inferred increase in fire activity at ~3.3 ka. Interestingly, we also found evidence for increased amounts of plant DNA during this period of increased biomass burning and or more frequent fires, alluding to the role of fuel loads and vegetation density in controlling fire regimes. Overall, our study sheds new light on the way climate and fire have shaped past biodiversity on Kangaroo Island, providing insights relevant to future fire management and further contextualising the complex human history of Kangaroo Island. Finally, this study demonstrates the potential for the preservation of *sed*aDNA dating back to at least ~ 7,000 years in an Australian lake and encourages the application of this novel proxy in the region.

Paleoenvironmental reconstruction of the last 14,000 years in the Bransfield Strait (Antarctica) using sedimentary ancient DNA

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Paleoenvironmental reconstruction of the last 14,000 years in the Bransfield Strait (Antarctica) using sedimentary ancient DNA

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The Southern Ocean is of critical importance to the world's carbon budget and global climate. Therefore, it is necessary to understand how the ecosystem will respond to future climate changes. Coastal regions such as the Bransfield Strait, Antarctic Peninsula, are particularly exposed to global warming. Using a genetic approach, like shotgun sequencing and diatom metabarcoding to sediment cores, past changes in the photoautotrophic community composition can be determined to derive information on the ecosystem's response to climate change. However, community changes in the Southern Ocean's past have rarely been studied using genetic methods. Here we show that *Phaeocystis antarctica* (haptophyte) was the dominant taxa during the remainder of the Antarctic Cold Reversal (14 - 13 ka BP) and that there was a shift toward generalists such as *Chaetoceros* (diatom) since 13 ka BP. This study shows a strong correlation between sea ice cover, water temperatures, and the photoautotrophic community in different climate periods. Furthermore, the results evidently demonstrate the dominance of *P. antarctica* during iron-replete times supporting its key functional role in the past Southern Ocean ecosystem. This study highlights the importance of surveying biodiversity by using shotgun sequencing to retrieve a comprehensive picture of the photoautotrophic community turnover and its consequences on carbon sequestration and cycling in the past.

Evolutionary populations genomics of Baltic Sea phytoplankton across the Holocene

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The Baltic Sea is currently challenged and under profound stress. Climate change, overfishing and eutrophication (mainly through fertilizers in agricultural waste water) are three of the main impacts that endanger the stability of the ecosystem nowadays. Additionally, the low biodiversity of the Baltic Sea increases the risk of destabilization. Since its formation after the last glaciation, the Baltic Sea has faced multiple periods of intense ecological changes. These changes were related to climate and anthropogenic factors, such as salinity and temperature shifts as well as increased nutrient loads. In the PhytoArk project, conducted jointly by researchers from the Leibniz Institute for Baltic Sea Research Warnemünde, the University of Konstanz, the Senckenberg Research Institute Frankfurt and the University of Hamburg, we are investigating phytoplankton changes during the Holocene of the Baltic Sea and integrating community and population dynamics into phytoplankton models. At the population level, we are tracing intraspecific genomic changes and potential evolutionary adaptions within and among the diatom *Skeletonema marinoi* and the dinoflagellate *Apocalathium malmogiense*. For this, we are using ancient DNA from sediment cores as well as genomic DNA extracted from resurrected cultures. These cultures are germinated from resting stages contained in the sediment. With this we aim to decode population dynamics and evolutionary changes related to ecological shifts to collect information to better understand current and future responses of these abundant phytoplankton species.

A high-resolution metagenomic exploration of Upper Lake Constance sediment over the past 14000 years

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The perialpine Lake Constance has experienced significant changes since the end of the Last Glacial, influenced by varying climatic and anthropogenic impact. Its large, deep Upper Lake, the basin of which formed during the Last Glacial Maximum, was influenced mainly by natural environmental changes through most of its history. Postglacial colonisation and climatic perturbations of the Holocene, for example, are among the processes that affected the ecosystem of the lake and its surrounding area. To characterise these changes, we utilise the archiving property of lake sediments and extracted multiple sedimentary DNA data series from a 24-meter-long core. Among them, a shotgun sequencing data series consisting of 34 samples spanning the last 14000 years was created and is presented here as a comprehensive representation of biological community over time. A significant vegetation change after the Younger-Dryas Boundary is recognised in the dataset. Subsequently throughout the Holocene, we observe a general increase in bacterial diversity in the lake, as well as an increase followed by a decline in vegetation and megafauna diversity at ~1300 years BP (AD 650). Through integrating time series of taxa from all trophic levels, we are aiming to reconstruct ecological changes and processes such as turnover in genetic diversity of key species, an endeavour to reveal the evolution of lake ecosystems under the ever-changing environment.

Phylogeny of Late Pleistocene and Holocene Bison from the south-eastern Alpine region and the Carpathian basin

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During the last 130,000 years, two species of *Bison* were traditionally acknowledged to be present in Europe: the steppe bison (*Bison priscus*), which appeared as early as the Middle Pleistocene and became globally extinct in the Middle Holocene, while the morphologically distinct osteological remains of the extant European bison or wisent (*Bison bonasus*) first appear in the fossil record around the start of the Holocene. Phylogenetic inferences based on mitochondrial DNA prove the existence of three clades in the last 50,000 years: Bp, which includes the steppe bison, and Bb1 and Bb2, which are related to the European bison.

Although several dozen Late Pleistocene and Holocene bison remains have been discovered in Slovenia and Hungary, genetic analysis has been mostly performed on (sub)fossils from Western Europe, Poland, the Caucasus and Siberia. Therefore, the aim of our study was to analyse the ancient DNA (aDNA) from teeth/bones found in these two regions in order to assign the specimens to the existing clades. For this purpose, we extracted the DNA from fossil remains, morphologically attributed to *Bison sp.*, in a specialised aDNA laboratory. By using an amplicon-based approach with a maximum amplicon length of 198 base pairs, targeting the 12S, 16S, ND2, COI, ND4 and cytochrome b regions of the mitochondrial DNA, we sequenced the amplicons on the Ion Torrent S5 next-generation sequencing system. We processed the sequencing results using an in-house developed bioinformatics pipeline, and constructed phylogenetic trees using the BEAST software.

We successfully amplified and sequenced aDNA from several samples, followed by the assembly of 2,195 bp long concatenated consensus sequences of the mitochondrial DNA. Our results show that Late Pleistocene *Bison* from the studied areas belong to the Bp clade, while the Late Glacial and Holocene specimens belong to the Bb2 clade. We did not detect the presence of the extinct Bb1 clade. Our research can therefore contribute new insights into the paleogeography of Late Pleistocene and Holocene bison in Central Europe.

Identification and engineering of woolly mammoth regulatory elements

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Changes in gene expression have been implicated in adaptation to many types of environmental stress, such as between high/low altitude and nutrient rich/poor environments, and even in speciation. However, most palaeogenomics have focused on changes in protein coding genes alone, due to the difficulty in recovering RNA from ancient samples and the quantitative biases associated with it, as well as the generally poorly understood role of regulatory changes in adaptation. Here we combine two complementary computational approaches to predict cis-regulatory elements in woolly mammoths and identify those that may be impacted by structural changes across different mammoth populations. We couple this with preliminary experiments on the functional impact these predicted changes have on gene expression, and the possible roles these changes may have on arctic adaptation. Given the increasingly important role gene expression changes are believed to play in adaptation, being able to accurately predict and engineering regulatory changes will be instrumental to current and future de-extinction and conservation projects.

Session 176: Tectonic and Climate-driven Landscape Evolution a never-ending challenge for modern society (Thoughts from LEMON project, INQUA - AIQUA)

Quantitative models in slow deforming, low-relief landscapes: example from the Central Po Plain (Italy)

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Landscape-changing events help constraining sedimentary basins' evolution during syn-tectonic orogenic belt growth. In low-relief and slow-deforming areas, as in many Quaternary foreland basins of the world, landscape evolution markers and tectonic rates are difficult to unravel and represent a topic for ongoing research related to seismogenic potential of active faults and related seismic hazards.

In this research, we describe and quantify the Quaternary tectonic modulation of the landscape during its response to glacial cycles along a buried thrust front of the Northern Apennines (San Colombano and Casale-Zorlesco thrusts). We focus on three subdued hills, which elevate above the latest Pleistocene-Holocene terraces of the central Po plain.

This study integrates multi-scale methods including geomorphological, sedimentological, stratigraphic, geo-pedological, and structural field surveys, constrained by C^{14} and OSL age determinations, borehole logs, and seismic images analysis for the deepest unconformities and fault surfaces reconstruction. We identified five Quaternary high-rank unconformities and intermediate-rank unconformities that were correlated from surface to subsurface. The architectural and chronological reconstruction gave the constraints to compute the 3D subsurface geological model. The deformation observed on the unconformities was restored, considering the sediment compaction and the tectonic component, by computing the slip on the buried faults with a trishear inversion. The resulting tectonic component of the deformation is presented as probabilistic slip rates accounting for the sources of uncertainty in the computation.

The investigated ramp anticlines underwent thrusting during the last 1.8 Myr with variable rates. Since the Middle Pleistocene, the San Colombano thrust moved faster than the Casale-Zorlesco one. The San Colombano hill registered the anticlinal collapse from the LGM. A post-glacial outwards propagation of the Apennine thrusts was buttressed by the opponent Alpine thrust-belt front and induced the entrenchment of the river network. The quantification of slip rates highlights how the climate-controlled sediment flux from the Alpine side of the basin was accommodated during the Apennine N-wards thrusting. Surface markers of this evolution are landforms such as relicts of uplifted planation surfaces covered by the latest Pleistocene weathered loess units, mildly tilted alluvial terraces and diversions of extinct meandering river traces on the latest Pleistocene plain.

Complex erosional response to uplift and rock strength contrasts in transient river systems revealed by 10Be and 26Al cosmogenic nuclide analyses

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Understanding the influence of bedrock lithology on the catchment average erosion rates of transient river systems crossing the strike of an active normal fault, and effect that different intrinsic and extrinsic factors have on the evolution of transient fluvial geomorphology remain major challenges for the tectonic geomorphology community. To investigate this problem we collected 18 samples for ^{10}Be and ^{26}Al cosmogenic nuclide analysis to determine catchment averaged erosion rates along the well-constrained Gediz Fault system in western Turkey, which is experiencing fault-driven river incision owing to a linkage event ~ 0.7 Ma. Combined with existing cosmogenic data we show that the background rate of erosion of the pre-incision landscape is 46 ± 46 mMyr^{-1} and erosion rates within the transient reach vary from 30 – 1330 mMyr^{-1}. Erosion rates weakly scale with unit stream power, steepness index and slip rate on the bounding fault, although erosion rates are an order of magnitude lower than fault slip rates. Conversely, there are no clear relationships between erosion rate and relief or catchment slope. Bedrock strength is assessed using Schmidt hammer rebound and Selby Rock Mass Strength Assessments, despite a 30-fold difference in erodibility there is no difference in the erosion rate at the reach scale between strong and weak rocks. We argue that for the Gediz Graben the strong lithological contrast effects the ability of the river to erode the bed resulting in a complex erosional response to uplift along the graben boundary fault, while weak co-variant trends between erosion rates and various topographic factors potential resulting from incomplete sediment mixing or pre-existing topographic inheritance.

Evidence of past tsunamis from mega and large earthquakes in Indian Ocean: Records from the last 8000 years, Andaman Islands India

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We report evidence of tsunamis from South Andaman Island obtained from a stratigraphic records of last 8000 years. In total seven tsunamis were identified in form of sand sheets resting over buried wetland soils. The youngest of these deposits represents the 2004 Sumatra-Andaman tsunami, whereas the older are likely correspond to historical tsunamis of 1881, 1762, and 1679 CE, and prehistoric tsunamis those occurred during 1300-1400 CE, 2000-3000 and 3020-1780 BCE, and before 5600-5300 BCE. The tsunami event of 1300-1400 was a mega event, had a wider effects in the Indian Ocean and is comparable to the 2004 tsunami. Based on grain size and thickness, the tsunamis assigned to 1679, 1762, and 1881 were confined to the northeast Indian Ocean. Sources have not been determined for the three earliest of the inferred tsunamis. Considering the OSL and AMS ages, distribution of tsunami deposits reported from countries adjoining Indian Ocean and correlation, we suggest a recurrence of 420-750 years for mega-earthquakes with different source, and a shorter interval of 80-120 years for large magnitude earthquakes.

Paleoseismological inferences and characteristics of medieval earthquakes along the Himalayan Frontal Thrust (HFT) from the Kumaun region of the Central Himalaya

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The Himalayan orogenic belt is one of the world's most seismically active mountain belts, accumulating strain during the interseismic period and releasing it as earthquakes. In the last century only, it has been the locus of some of the largest continental earthquakes in the world. The recent 2015 Gorkha earthquake shade on our understanding of the Himalayan earthquakes. Paleoseismological, investigations of the last two decades all along the Himalayan arc have suggested that greater Himalayan earthquakes have ruptured the frontal part in recent as well as in medieval times. With the recorded history of earthquakes, the Central Himalaya experienced several large and great earthquakes in medieval times. There exist large uncertainties in determining the most recent surface rupturing event in the Central Himalaya. Recently we excavated a trench on a 15-20 m uplifted alluvial fan surface along the Himalayan Frontal Thrust (HFT) in Haldwani, Kumaun (Central) Himalaya. We collected 27 samples from different lithounits for Optically Stimulated Luminescence (OSL) dating and 16 Charcoal samples for Radiocarbon dating. The dating of these samples will help to bound the events which deformed these surfaces. Furthermore, we have collected samples for OSL dating from the older alluvial fan surfaces, River Terraces, and Fault Scarps of the region. The great earthquake of CE 1505 and the most recent one, which occurred in CE 1803, significantly impacted the region. However, there is a debate among the scientific community over the surface rupture of the CE 1803 earthquake and the spatial extent of the great CE 1505 earthquake in the kumaun region. This study mainly focuses on understanding past earthquake activity and the uncertainty associated with them in the Kumaun region of Central Himalaya.

Geomorphologic analysis along the Palomares Fault (SE Iberian Peninsula): Evidence of tectonic activity in low deformation rate regions.

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The Palomares Fault (PF) is a main N-S oriented strike-slip fault in the Eastern Betics Shear Zone (EBSZ), a crustal-scale transpressive fault system that absorbs a significant part of the current shortening between the Eurasian and the Nubian plates. The system also has generated several damaging earthquakes since historical times, which demonstrate its catastrophic potential. Despite this, the EBSZ faults are considered moderate to slow-active faults as their slip rates do not exceed 2 mm/yr. In the case of the PF, slip rate estimates from different geologic markers are between 0.01 to 0.42 mm/yr. These values are about one or two orders of magnitude lower than the other faults in the system, where paleoseismic studies have been done providing more reliable data. The expression of the PF is also not as clear as the others; its deformation is distributed in several fault strands forming a very wide fault zone (1 to 4 km approximately) and its vertical deformation is also lower, showing mainly left lateral movement. Consequently, and especially in its northern termination where the fault trace has a more E-W orientation, the area does not present a prominent relief nor extensive alluvial deposits, which makes it difficult to determine and characterize its recent activity. Therefore, a new study has been proposed with the aim of well characterizing the fault, and obtaining new paleoseismic data, the first stage of this study is the geomorphological exploration of the area. A neotectonic and geomorphologic mapping of the entire fault zone has been carried out, recognizing the main tectonics structures affecting Quaternary alluvial fans and identifying their generations. Also, different geomorphologic analyses have been performed using several methodologies and visualization approaches of digital elevation models, such as Red Relief image maps or Swath Profiles. From these analyses, new sites for paleoseismologic trenches have been selected that will likely provide new data of the fault and improve the reliability of the slip rate estimates.

Late Quaternary coastal uplift of southwestern Sicily, central Mediterranean Sea

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Mapping and luminescence aging of raised marine terraces and aeolian ridges along an ~90 km coastal stretch in southwestern Sicily provide the first quantitative assessment of vertical tectonic deformation in this region, which spans the frontal part of an active thrust belt. We recognized a staircase of eleven terraces and nine related aeolian ridges. The elevation profile of terraces parallel to the coast shows a >90 km long bell-shaped pattern, onto which shorter-wavelength (~10 km long) undulations are superimposed. Luminescence ages from terraced beach deposits and aeolian sediments constrain the position of paleoshorelines formed during MIS 5e, 7a and 7c, with a maximum uplift rate of ~0.75 mm/a, and indicate a late Middle-Late Pleistocene (80-400 ka) age for the sequence of terraces. The elevation of Lower Pleistocene morpho-depositional markers points that uplift may have occurred at similar rates at the beginning of the Early Pleistocene, but almost zeroed between ~1.5 and 0.4 Ma before the recent renewal. The uneven elevation of Middle-Upper Pleistocene paleoshorelines observed moving along the coast documents that uplift embeds both a regional and a local component. The regional, symmetric bell-shaped uplift is related to involvement in the thrust belt of thicker crustal portions of the northern African continental margin. The short-wavelength undulations represent the local component and correspond to actively growing bedrock folds. The present study contributes to unravel the different spatial and temporal scales of deformation processes at a collisional margin.

3D modelling for the reconstruction of the pre-anthropic landscape, the case study of the plain of Palermo (Italy)

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The reconstruction of the geological model of the subsoil in urban areas is a very topical problem. Defining the geometry and extension of the lithotypes is useful for the definition and implementation of urbanistic plans but, almost in highly populated areas, it is not always possible to carry out direct surveys that provide information on the subsoil. Therefore it appears extremely helpful constructing geological models defined based on available subsoil information. In this respect the Palermo plain can be consider as an effective case study.

A worthwhile support for the geological model definition comes from a massive data collection managed by the University of Palermo. Since about twenty years, the Department of Earth and Marine Sciences has been involved in the creation of a database where there are currently collected data such as boreholes, geological section and geotechnical parameters. The database was created by collecting the stratigraphies provided by public bodies, research institutes and private companies. The surveys are geo-localized and lithologies nomenclature has been homogenized and standardized. This work of analysis, description and re-nomenclature of the stratigraphies has led to the identification, definition and partial mapping of the anthropogenic covers that are widely present. This database is the basic tool for creating a 3D model of the Palermo plain. The development of this latter gives several advantages among which the reconstructing of geological surfaces through the stratigraphies boreholes interpolations. Applying this work on the available stratigraphies is possible to reconstruct the paleo-morphological and paleo-topographic features of the land surface in a pre-anthropic age and to define the continuous and constant transition from the ancient natural to the urbanized landscape through the classification and placement of anthropic deposits.

This reconstruction is handy to identify the original natural constraints, such as presence of watercourses, which influenced the primary anthropized landscape evolution and to understand how several neighborhoods built inside constrained areas are nowadays subjected to geological hazards.The achieved model can be verified, corrected and validated comparing it with the different historical and cartographic representations of the Palermo plain that describing the evolution in time of the urbanized landscape.

Time series of remotely sensed shoreline variability: possible implication for climate change analysis?

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The recent development of the remotely-sensed shoreline extraction technique improved investigations about Shoreline Change Analysis. Such analyses base on time series to quantify the recent coastal landscape evolution that could be driven by climate changes, tectonics, and anthropic processes. Improving our understanding of the past evolution could provide critical information for forecasting future coastal landscape scenarios for better coastal management and mitigating the natural hazard linked to coastal erosion processes.

In this work, we use an in-house developed semi-automatic geospatial model to quantify the shoreline evolution using a dataset ranging from a single month up to 40 years with a sub-pixel resolution. Shorelines were extracted from a dataset of satellite images with various geometric, radiometric, and temporal resolutions into sandy coasts of Sicily (central Mediterranean) affected by similar daily tide excursions ranging from 15 to 35 cm. Obtained results demonstrate the high potential of satellite observations to quantify both the rate of beach accretion and retreatment over roughly 40 years and the variations in the sedimentary budget using monthly observations.

A periodicity of 3.5 years in the shoreline oscillations highlights the potential of considering the shoreline evolution as a proxy for understanding climate changes linked to the atmospheric circulation pattern in the Mediterranean basin.

Session 177: Factors influencing the diversity of loess sedimentary environments and the resulting variability of palaeoclimatic and palaeoenvironmental signals

Differentiation of loess records and landscapes based on a European Loess map

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Here we present a conceptual model of loess landscapes based on the spatial analysis of loess and loess facies in Europe. Our model conceptualizes loess formation in a ‘loess-triangle’, which corners represent the three extreme eco-zones of nival, humid, and arid environments. ‘Typical’, continuous and silt-sized dominated loess is placed in the triangle’s center. We identify three modes of loess formation that are controlled by climatic factors, namely humidity and temperature, which in turn constrain the prevailing vegetation. Mode 1: Periglacial and tundra loess, Mode 2: Temperate and subtropical loess, Mode 3: Desert margin loess. Our model is based on a new European loessmap which distinguishes six main genetic domains and 17 subdomains. For the subdivision we used the following criteria: (1) role of silt production areas, (2) link to sub-catchments, as rivers are very important regional silt transport agents, (3) occurrence of past periglacial activity. Additionally, the sediment distribution is combined with elevation data to investigate the loess distribution statistically as well as visually. Whereas periglacial and tundra loess were deposited in the northern European loess belt north of the Alpine Mountain Belt, typically desert margin loess occurred especially in dry steppe environments in southeastern Europe and in semi-desert environments in Spain. The temperate and subtropical loess and the related paleosols formed mainly in regions with a distinct dry season (summer or winter, e.g. towards the Mediterranean regions with winter rainfall or in monsoonal regions with summer rainfall). The conceptual model also has relevance if used vertically. For example, at higher elevations in semi-arid regions of central-eastern Europe humidity-controlled forest belts do not contain any loess deposits. The uppermost boundary of loess in mountainous areas is periglacial loess of Mode 1, whereas the lowermost one in the adjacent lowlands can be typical steppe to desert margin loess of Mode 3, especially south of the Alps and Carpathians. For the latter regions, there are still debates on the role of glaciers and deserts on loess formation. We conclude that the semi-arid drylands are one of the main regions for “typical” loess formation.

Holocene Arctic loess deposits around Kangerlussuaq, Greenland

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The current pace of Arctic climate change is unprecedented in instrumental records. This change is of wide significance because many Arctic-specific climate feedbacks have global impacts. It is therefore crucial to examine geological archives of past Arctic environments in order to understand abrupt Arctic change. Loess deposits are preserved around the ice-free area of Kangerlussuaq, western Greenland, and potentially provide a means for understanding climate change on Greenland during the Holocene. However, to date there are no detailed depositional chronologies or climate proxy records for these sediments, limiting their use in understanding past Arctic change. Here we sample loess and combined peat-loess sections around Kangerlussuaq for detailed luminescence and radiocarbon dating, as well as testing of possible climate proxies. Preliminary sampling yielded few organic macrofossils, meaning that initial radiocarbon dates were obtained on bulk organic matter. While the results are stratigraphically consistent, this approach is susceptible to carbon contamination during soil formation. Luminescence dating via standard quartz optically stimulated luminescence methods was not possible due to weak quartz signals, but the post IR infrared stimulated luminescence (IR50; pIR IRSL180) signal yielded reproducible and stratigraphically consistent ages. However, Holocene pIR IRSL ages are susceptible to overestimates due to 'partial bleaching', where solar exposure is insufficient to completely zero the signal. Comparison of bulk organic matter ^{14}C and pIR IRSL ages from one test site close to Russell Glacier shows that these two independent methods are offset from each other by c. 2 thousand years. We present further results of tests for the causes of these offsets between different age-dating techniques. We also present results from initial climate proxy analyses, including mineral magnetic, particle size, geochemistry, and bacterial brGDGT approaches, revealing fluctuations in environment since initial loess formation, at c. 4-6 ka.

A Classic Loess Transportation Surface in the Great Lakes Region, USA

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Loess transport is often initiated or assisted by saltating sand. As long as sand remains available on devegetated surfaces, silt deflation may continue to be active, and deposition of loess may be difficult to accomplish. These types of loess generation-transport systems, first described by Joe Mason and colleagues in 1999 (Geomorphology 28:223-236), epitomize loess transportation surfaces. On a loess transportation surface, sand is widely available, winds are strong, and vegetaive cover is minimal. Loess transport will continue until a topographic barrier such as a deep valley or an abrupt upland impedes the saltating sand. Thick, sand-poor loess deposits typically accumulate downwind from the barrier. In this talk, I describe a classic loess transportation surface/system in western Wisconsin, USA. Across the transportation surface, loess is absent, or exists only a thin sandy-loamy-silty eolian mantle. The transportation surface has two main sand sources: glacial outwash and isolated hills of friable sandstone. Most of these sand sources occur in the western (upwind) parts of the transportation surface. Eastward, eolian deposits remain thin and loamy, with bimodal (sand and silt) grain size distributions. Thick loess deposits occur downwind of two types of locations: (1) high, isolated sandstone hills, and (2) the valley of the north-to-south flowing Black River. Maps of loess grain size and distribution, relative to these two types of topographic barriers, comprise the bulk of this talk. These data clearly illustrate how loess texture, thickness, and distribution are related to topography, in areas where sand is available. This work may help others explain small- to medium-scale loess patterns on the modern-day landscape.

Environmental characterisation of Greenland Interstadial 2 by combining high resolution molluscan records and radiocarbon dating of earthworm calcite granules and mollusc shells

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In Upper Weichselian loess sequences pedogenic horizons (mostly gleysols) are typical features documented in many profiles across the European Plain. Their site-to-site correlation was long precluded owing to uncertainties of luminescence dating techniques exceeding their temporal spacing. In western and central Europe, the use of earthworm calcite granules (ECG) overcomes the scarceness of charcoals and bones in loess sequences. Furthermore, their recent correlation with global Dansgaard-Oeschger climate events demonstrates that they can be correlated over long distances.

The youngest of these pedogenic units, named Nagelbeek Complex, constitutes an interesting study case owing to its more complex structure made of at least one gley horizon and one more or less gleyified humic horizon in the area of the eponym site, whereas it is farther mostly represented by a single pedogenic horizon of variable nature. Moreover, its age often lacks of precision and it is poorly documented from a molluscan point of view. Closer from the surface it is often degraded by subsequent Lateglacial-Holocene pedogenetic processes. Otherwise, its carbonate content ensures as for older pedogenic horizons the good preservation of ECGs and mollusc shells, which allows for radiocarbon dating and palaeoenvironmental reconstructions respectively.

New ECG-based radiocarbon ages around 23-22 ka obtained in several west-European sites, one of which close to the Nagelbeek quarry, strengthen its correlation with Belmen and Elfgen soils of the Eben Zone and with Erbenheim soil 4 in Germany, as well as with Greenland Interstadial 2. This agrees with the age of 24.3-24.4 ka estimated for the directly underlying Eltville tephra. Molluscan records help depicting environmental changes associated with its deposition dynamics and with the spatial variability of its facies. Contrary to older pedogenic horizons, the most striking point is the absence of strong molluscan abundance increases in the most northern sites, which matches with the absence of LGM human settlements.

Overall, this first attempt of mapping GI 2 molluscan fauna in western and central Europe provides new information about the spatial heterogeneity of periglacial loess environments but also raises questions about the specificities (duration, magnitude…) of the triggering climate oscillation.

Geochemistry and source characterization of late Pleistocene aeolian deposits in Dolni Vestonice, Central Europe (Czech Republic)

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Dust deposits hold an important record of present and past climate and environmental changes. Hence, identifying dust sources and spatial distribution is useful in reconstructing past climate conditions and atmospheric circulation. Dust provenance can be traced by its chemical composition and changes in radiogenic isotopes such as Sr, Nd, and Pb. During Marine Isotope Stage (MIS) 5, two types of peculiar aeolian deposits were identified in central Europe: so-called “eolian silts” (ES) and “marker silts” (MS) sharply situated on top of soil units and are correlated with climate records that represent abrupt cooling such as cold stadials in the $\delta^{18}O$ Greenland record. The formation of these silts and their source is unclear yet and should be further investigated. This study aims to characterize their provenance and trace possible atmospheric circulations responsible for their deposition.

We investigated the chemical (major and trace element) and radiogenic isotope (Pb, Nd, Sr) composition of a continuous sedimentary succession in Dolni Vestonice (DV), Czech Republic, which spans the last 110 ka and contains the silt units of interest. The different geochemical analyses were performed on different grain fractions (<5, 5-20, 20-63, >63 μm) in order to distinguish between proximal and distal material sources.

The distribution of the trace elements in the DV sediments generally agrees with the known values from various loess sites throughout Europe. The fine sediment fractions are depleted for most elements with respect to the coarse fractions suggesting a difference in sedimentary protoliths. According to the radiogenic isotopes, it seems that during MS deposition, the local source is more significant, probably coming from the east. While, during the ES deposition, there was moisture contribution from the North Atlantic.

Model of loess sedimentation in south-west Poland

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Characteristics of the depositional environment on the basis of studies of loess-soil sequences in a selected region require a reliable paleogeographic database. Moreover, to be able to create deposition models it is not enough to analyze only one sequence but at least two, located in the most characteristic places of the region. Convenient conditions are found in southwestern Poland, where archival results from many sequences are available. These studies have contributed an unusually large important information on loess sedimentation. The paleoenvironmental interpretation was extended to include the results of multidisciplinary studies of loess-soil sequences in Zaprężyn and Biały Kościół, which, i.e. detailed grain size analysis, spectrophotometric color testing, and OSL dating results in two independent laboratories were used. These two profiles are located less than 60 km apart on a north-south line. They represent two main loess areas in Lower Silesia: Trzebnica Hills and the Niemczańsko-Strzelińskie Hills. The obtained chronostratigraphic results were related to the basic Weichselian division, taking into the isotope-oxygen stages, which made it possible to create a model of the sedimentation conditions of the loess of southwestern Poland.

The results of the present studies lead to the following conclusions.:

- The occurrence of several morphoclimatic zones directly related to the migration of the Fennoscandian Ice Sheet was distinguished. Moreover, the study indicates that these zones clearly changed their boundaries. The meridional location of the two studied loess-soil sequences was helpful in capturing this phenomenon. The information recorded in the sequences allows concluding that the conditions of the depositional environment were slightly different despite their fairly close location relative to each other.
- Despite the apparent differences, it is possible to find features that indicate some commonalities. In particular, in loess from earlier stages of dust sedimentation during MIS4. These common features act as stratigraphic markers of a trans-regional nature.
- The best-preserved loess was deposited during the last “cold” isotope-oxygen stage of MIS2. Studies of these units indicate a rapid rate of dust accumulation, from local sources.

Paleocryogenic phenomena in the periglacial loess-paleosol sequence of Ukraine

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Aeolian-deluvial loess sediments, which form a thick loess-paleosol sequence (LPS), are the most common type of continental Quaternary sediments in Ukraine. They cover about 70% of the territory of Ukraine. Loess is not widespread in the Ukrainian Polissia, only isolated loess islands are located here, and it does not occur in the Ukrainian Carpathians and Crimean Mountains. The total thickness of the Quaternary loess-paleosol cover reaches a maximum of 40-50 m, and it does not exceed 20-30 m on average. The Quaternary LPS is divided into separate loess, paleo-soil, and paleocryogenic horizons. Evidence of permafrost development is recorded in the form of various paleocryogenic phenomena that are unambiguous witnesses of the loess formation in cold periglacial conditions.

We present the materials of a comprehensive study of the LPS of the Right Bank of Ukraine (Volhyn-Podolian Upland, Forecarpathian). Many reference sections were studied using modern methods of Quaternary research. Paleocryogenic phenomena were also widely analysed. In the Middle and Upper Pleistocene, it was detected at least eight paleocryogenic stages occurred in the studied LPS. The oldest one (Boyanychi stage) is dated to the beginning of MIS 8. Older paleocryogenic horizons have not been discovered yet. Therefore, there is every reason to claim that periglacial conditions were established in the west of Right Bank Ukraine at least eight times, in which permafrost developed.

Evidence of various paleocryogenic phenomena was found in the Pleistocene LPS. Among them are soil movements resulting from solifluction processes, viscous plastic deformations within former active layers, small and large-polygonal frost cracking, cryogenic texture formation, etc. All these phenomena have been studied in detail.

The performed studies unequivocally indicate that Pleistocene paleocryogenesis played a significant role in the formation of the composition and physical and mechanical properties of sediments of the LPS of Ukraine, and the Krasyliv (Final Pleistocene, MIS 2) paleocryogenic stage in addition significantly influenced the modern relief.

Problems from periglacial environments for luminescence dating of loess

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Luminescence ages obtained from last glacial–interglacial Polish loess palaeosol sequences (LPSs) by several established current protocols are presented. 38 new optically stimulated luminescence (OSL) ages from fine-grained (4–11 µm) quartz separates extracted from four LPSs, measured in the Bayreuth Luminescence Laboratory, Germany, are reported. The investigated sections are situated in Lower Silesia, the Sandomierz Upland in central Poland, and the Volhynian Upland in the east. From one Silesian section (Biały Kosciół) 12 new post-infrared infrared stimulated luminescence (pIRIR) ages are presented in addition to the quartz ages of identical sample material. The obtained ages are compared to already published independently elaborated middle-grain (45–63 µm) and coarse-grain (90–125 µm) quartz ages and pIRIR ages from fine grains produced in the Gliwice Luminescence Laboratory (Poland). This comparison shows that in many cases the middle- and coarse-grain quartz ages underestimate the fine-grain quartz ages, but a general rule has not been able to be established so far, likely due to different geological origin of the quartz grains. Even fine-grain quartz ages ≥ 50 ka may be underestimated with respect to lithostratigraphic expectations. For pIRIR ages, however, no evidence for age underestimates has been found in the studied sections, but they are more easily prone to age overestimates due to unknown residual doses at deposition in a periglacial environment. Basic agreement between the luminescence-based chronologies elaborated in the two involved laboratories can be stated for the first time in contrast to other previous studies. The observed age differences are, however, critical for the accurate time bracketing of geomorphologic and pedostratigraphic features and for their attribution to marine isotope stages. Alternative interpretations are discussed including possible periglacial mirroring of pre-LGM ice advances (Ristinge and Klintholm advances) in the southwestern Baltic Sea area. In order not to leave the users alone with the decision about the most credible dating, the suggested way forwards is to simultaneously apply various luminescence dating protocols including different quartz grain sizes and pIRIR from fine polymineral grains, as an honest approach to reliable time bracketing of geomorphological processes and stratigraphic events under debate.

Session 179: From coastal geomorphology to earthquake hazard (F-Coast2EHZ): new perspectives and multidisciplinary approaches

"The time when Bali shook" : geomorphological and geohistorical approach of the complex natural hazards cascade in the north Bali in November 1815

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Seven months after the Tambora eruption, whose ash fallout covered Bali to a thickness of 20-30 cm, a series of natural disasters occurred in November 1815 in north Bali. An earthquake (Ms 7), whose epicenter was located along the Flores Fault, caused a tsunami and the collapse of a mountain slope, which evolved into a gigantic debris flow that engulfed Singaraja city. These cascading hazards have killed nearly 12,000 people. Current knowledge of this series of disasters, rooted in Balinese memory, is based solely on written sources, but has never been scientifically studied.

The aim is carrying out an in-depth analysis of the cascading disasters that struck Bali in 1815, from the root causes and the chronology of the natural hazards to their environmental and societal effects at different geographical scales. Indeed, the hazards involved are poorly understood: the tsunami described in the historical sources is unknown or confused with a flood, and the deposits have never been identified. The cause of this possible tsunami is also uncertain (earthquake or arrival of the mass landslide into the sea). The origin(s) of the debris flow looks complex: based on local belief, it was triggered by the emptying of the lake due to a breach of the caldera rim, which remains doubtful considering the geomorphological setting. It is likely due to a deep earthquake-induced landslide(s), to which was added a multitude of volcanic debris flows (lahars) due to the remobilization of Tambora deposits. The trajectory of the debris flow remains vague, the delimitation of the coastal areas impacted by the tsunami is unknown, as well as the magnitude of the different phenomena (volume of the debris flow, height of the tsunami) and their chronology.

To solve these issues, we combine transdisciplinary approach with geomorphological field surveys, sedimentological analyses, and geohistorical studies through the exegesis of local (Balinese) and colonial narrative sources (English and Dutch colonizers). These approaches allow characterizing the precise sequence of the hazards and their mechanisms; reconstructing the post-disaster landscape of the ancient kingdom of Buleleng, to improve our understanding of past, present, and future coastal geohazard risk in Bali.

Emerged Coral Terraces and Beachrocks in Southwest Panay, Philippines: Clues to Holocene Relative Sea-Level Changes and Coastal Deformation Along the Northern Negros Trench Forearc

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The Negros Trench is one of the active subduction zones in the Philippines located in the marginal Sulu Sea. Despite its potential to generate strong to great earthquakes, the seismogenesis of the Negros Trench remains poorly understood. In this study, emergent coastal features have been investigated in southwestern Panay, facing the trench, to elucidate clues of prehistoric coastal deformation and relative sea-level changes. Real-time kinematic (RTK) GNSS and drone surveys were conducted to determine the elevations relative to the tide datum and the extent of emergent beachrocks and coral terraces. In a small island off southwestern Panay, emergent coral terraces were present only on the western side facing the trench at elevations ranging 1.52–1.95 m amllw with double notches indicating abrupt relative sea-level change. In other coastlines of southwestern Panay, emergent fossil corals were also mapped at elevations ranging 1.25–3.45 m mllw. Two parallel but discontinuous strips of emerged beachrocks, about 100–200 m long, were also mapped in southwestern Panay. Petrographic analysis and $\delta18O$ and $\delta13C$ ratios (Z) of beachrock cements reveal isopachous prismatic cement and marine origin (Z = 126.74–130.47), respectively, indicating subtidal beachrock development. The NE segments of both strips have lower maximum elevations (1.46 and 1.47 m amllw) than the SW segments (2.45 and 3.61 m amllw). These differences in maximum elevations are attributed to variations in depth of formation, where the NE segments are presumed to have formed at deeper portions than those in the SW. Radiocarbon dates of subtidal beachrock cements indicate that the first beachrock strip development occurred around 5855–4508 cal BP, whereas the second strip formed around 3128–1825 cal BP. Both ages range by about 1400 years of beachrock development and are attributed to a period of relative sea-level stability. Disruptions in subtidal beachrock development are linked to abrupt relative sea-level fall that could be tectonically induced. U-Th dating of emerged fossil corals and their correlations with the emerged beachrock strips may support this inferred coseismic uplift.

Mid-Holocene Paleo Sea Level and Uplift History Deduced from Emerged Sea-Level Indicators in Poro Island, Luzon, Philippines

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Past sea levels are deduced from sea-level proxies which give insights into the relative sea level at the time of their formation. In northwestern Philippines, at least three sea-level highstands were reported, having higher elevations than the highstands in central Philippines. Proxies such as marine terraces and coastal notches are present in Poro Island, Luzon, a 1.21 sq km landmass located 80 km east of the Manila Trench where the Eurasian plate subducts eastward beneath the Philippine Mobile Belt. These geomorphic features were characterized and correlated with other sea-level proxies in the area to constrain the sea-level history in the area. The marine terraces were delineated through surface classification modeling, using slope and roughness values from DEMs, and were validated through topographic profiles from Real-Time Kinematic (RTK) surveys using a GNSS receiver instrument. Two to nine terrace steps, with elevations ranging from 1.4 to 25 meters above mean sea level (m amsl), were validated during fieldwork. Terraces in the western section of the island occur ~20 cm higher than those in the eastern and southern sections indicating an eastern tilt for the island. Terrace widths range from 0.3 to 7 m and are composed of coral reef and beachrock with the older terraces being overlain by sand and terrestrial debris. Coastal notches have widths of 0.2 to 0.9 m and heights of 2 to 6 m amsl. Radiocarbon dating of fossil corals collected from the lower terraces (1.3 to 3.0 m) reveals ages of 6070 ± 30 BP to 6790 ± 30 BP, indicating emergence after the mid-Holocene highstand. Correlating these results with the nearby proxies in the region revealed that the estimated average uplift rate in Poro Island, which is 0.35 mm/year, is similar to those observed in Badoc Island, a landmass approximately 20 km north of the study site. These uplift rates in Poro and Badoc islands are lower than those measured in other tectonically active sites such as Papua New Guinea, New Zealand, and Japan. Studying sea-level proxies is important in reconstructing paleo sea levels and determining uplift activity in tectonically active regions such as northwestern Luzon.

Quantifying Quaternary uplift of southern Sumatra using marine terraces

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Marine terraces are exposed paleoshorelines that form in response to land uplift and changing sea level. These landforms are found in many tectonically active regions, and dated terraces are commonly used to quantify coastal uplift rates over timescales of 10^4–10^5 yr. However, sea-level highstand elevation remains poorly constrained for many interglacial periods, and numerous terrace sequences—particularly in tropical regions—have not yet been surveyed or dated. Along the west coast of southern Sumatra, Indonesia, approximately 250 km from the Sunda Trench, we have identified previously unmapped flights of terrace landforms up to 300 m above present sea level. To estimate the age of this currently undated landscape, we have developed an inverse approach that calculates probable uplift rates while encompassing uncertainties in observed terrace elevation, depth of terrace formation, and the timing and magnitude of sea-level highstands. Swath profiles from digital terrain models were used to measure apparent terrace shoreline angles, and preliminary inversion results suggest local uplift rates of less than 0.5 mm yr−1 since uplift began during, or before, MIS 7e. We infer that these terraces formed in response to long-term Pleistocene−Holocene uplift of the coastal environment and discuss whether mapped (or unmapped) onshore or offshore faults could generate the observed surface deformation.

The impact of lithological variations in the evolution of recent drainage systems: the study case of the peri-Adriatic belt

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Studying Quaternary landscape evolution is key for the understanding of active tectonics. In coastal areas, marine terraces, notches, and abrasion platforms are commonly used to infer active tectonics, but when outcropping lithologies (such as clays and sands) are too weak to allow good preservation of these landforms, the study of the drainage system can help the understanding of recent and active tectonics. However, river metrics are sensitive to many factors besides tectonics, such as climate and lithological variations, that can complicate the interpretation of the data. On the east coast of the Italian peninsula, the Quaternary (<900 ka) uplifted peri-Adriatic belt is a type example of a coastal area where drainage features are widely used to infer recent tectonics. In this area, metrics like river steepness and changes in stream directions appear to suggest the recent activity of blind thrusts, interpreted as resulting from eastward propagation of Apennine compression. However, there are no indications of active surface deformation, such as faults or tilted stratification. The geology of the peri-Adriatic belt reflects the evolution of a marine basin progressively transitioning to a coastal system with widespread fluvial deltas. These deltas are now uplifted and form resistant conglomeratic bodies superimposed on and surrounded by marine clays of the peri-Adriatic bedrock. In this study, we explore how the morpho-stratigraphic features of a recently uplifted coastal system may condition the formation of the drainage network and generate features similar to those indicative of active tectonics. By combining field observations, morphometric analysis, and landscape-evolution modeling, we demonstrate how a young landscape such as the peri-Adriatic belt is strongly influenced by the morpho-stratigraphic characteristics of the eroded bedrock, which can trigger changes in river directions and channel steepness that resemble features developed by the activity of blind thrusts. Our interpretation does not exclude active tectonics in the peri-Adriatic belt, but focuses attention on the impact that lithological variations may have on the drainage network development and on the inference of the recent tectonic regime.

Anfeh Peninsula in coastal Lebanon: evidence for past coastal geo-hazards.

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Located over the coast of northern Lebanon, Anfeh promontory is at the intersection between land and sea, recording the imprints of various coastal processes over the tectonically growing Mount-Lebanon range. The area holds important archeological and cultural sites from prehistoric periods to modern times. The most prominent morphological feature in the area is a narrow 70 to 100 meter and ~ 480-meter-long peninsula oriented almost E-W at right angle to the general direction of the coastline. The top of the peninsula stands at around 14 masl and drops regularly from North, West and South over a wave-cut platform rimmed with vermetid bioconstructions. The peninsula is occupied by the mainly medieval site of Anfeh Castle, invested since more recent times by artificial salt pans that covered and preserved most of the initial landscape and remains. The detailed survey of the area reveals the rich potential of the site, where evidence of relative sea-level changes, tsunami deposits and fault rupture are documented. The site is also actively shaped by the coastal erosion and karstification processes. Focusing on the tectonic signal, inspecting the remains of the Anfeh Castle revealed evidence of surface rupture and destruction along a previously unknown NW-SE oriented fault system. Foundation structures and geomorphic features are offset, mostly right-laterally, by few centimetres to few decimetres. However, the wealth of available data on the medieval historical seismicity in Lebanon, has no mention of an earthquake in this area. The surface rupturing event at Anfeh may relate to the large AD 1202 earthquake and seismic crisis that essentially ruptured the Yammouneh Fault segment of the Levant Fault System. The newly identified fault at Anfeh Castle can also be traced in the near offshore morphology and could be responsible for the tsunami waves associated with the AD 1202 events. Thus, Anfeh Castle is the first documented archaeological site in Lebanon showing evidence of direct seismic rupture. The newly identified active fault and earthquake event will add to the resolution of the seismic hazard assessment in this part of the Mediterranean.

Landscape Evolution and Paleo Seismicity at central part of the Shimabara Bay, Kyusyu Island, Southwestern Japan

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The Shimabara Bay is an elongated bay of 85 km-long with maximum width of 20 km, locating at central part of Kyushu Island, southwestern Japan. At the central part of the bay, the Unzen Fault Group (UFG) and the Futagawa Fault Zone (FFZ) develop a graben structure which comprises the Beppu-Shimabara Graben. UFG is composed of active normal faults and FFZ should be composed of active dextral and normal faults. As a part of active faults survey consigned by MEXT, we conducted high-resolution MCS and offshore drilling survey at central part of the Shimabara Bay. At the both side of UFG, we obtained 40.0 m long sedimentary core at the subsiding side (46.7 m BSL) and 35.3 m long core at the upthrown side (33.1 m BSL) by offshore drilling survey. At the subsiding side, the core is composed of muddy sediment of LGM and subaerial and submarine sediment of the post-glacial period. At the upthrown side, the core is composed of muddy sediment of MIS 5, pyroclastic sediment of Aso-4 eruption (89 ka) and post-glacial sediment. We determined sedimentary age model based on radiocarbon ages from 20 horizons and identification of volcanic deposits. The submarine geology of the Shimabara Bay was clarified owing to high-resolution seismic sections and sedimentary cores obtained by this study. We found a fluvial surface of erosion is displaced 33-38 m vertically by UFG. Assuming the surface was formed during 21.0-16.5 ka, the averaged vertical slip rate of UFG should have been 1.6-2.3 m/ky. At subsiding side of UFG, post-glacial succession is about 30 m thick and cumulatively displaced by associated faults of UFG. According to sedimentary ages determined by drilling survey, 3 or 4 earthquakes have occurred at UFG since 16.5 ka, at least. We demonstrated combination of offshore drilling survey and high-resolution MCS may provide convincing and detailed imagery of landscape evolution and elucidate paleo seismicity of active faults.

Drifting pumice on the Okinawa Main Island and Ishigaki Island: 2021 November and December and later changes in occurrence

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A large amount of pumice was erupted by a large-scale eruption of submarine volcano of Fukutoku-Okanoba on August 13, 2021. Since early October, it has gradually drifted to the Daito Islands, the Okinawa, Amami Islands and the Sakishima Islands. This drifting pumice derived from Fukutoku-Okanoba is the first time in 35 years since 1986 in these areas. Okinawa Main Island has aligned more than 100 km from northeast to southwest, and is convenient to consider the distribution characteristics of drifting pumice, so we conducted a field survey on drifting pumice in November 2021. After that, in order to verify the process of which drifting pumice is recorded as geological information, a field survey was conducted in Ishigaki Island in addition to the Main Island in December, 2021. In this presentation, we will report typical occurrence on both islands.
On the Main Island, we will compare the survey results for November and December 2021. First of all, in Sashiki in Nanjo City, the entire surface was covered at the time of the November survey, but the drifting pumice is almost half in December. Yamada in Onna Village, Nakijin Village, Hedona and Oku in Kunigami Village, the loss of pumice is progressing. In this way, in many places on the Main Island, the pumice erosion and decrease are continuing, but in the Haneji Inland Sea located on the east coast of the Motobu Peninsula, many drifting pumice still occupies the sea surface even in December. This is probably due to the direction of the prevailing wind or coastal morphology. In the eastern edge of Inamine in Nago City, which is adjacent to the east of the Haneji Sea, a large amount of pumice was about 2 meters behind the breakwater of about 3 meters in a hight. Here, there is a pum of pumice with a width of 2 m just below the breakwater, but drifting pumice is no longer found in the coastal area. This is thought to have been lifted by waves or strong winds, but at this stage, the detailed transport mechanism is unknown.

Session 180: Sedimentary record of past catastrophic coastal flooding (tsunami, storms)

New insights from organic geochemistry into paleo-tsunamis – Maita River Valley, Noda (Japan)

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Organic geochemical indicators have proven suitable to identify and characterize deposits of modern tsunamis, such as the 2011 Tohoku-oki tsunami. For instance, provide anthropogenic organic proxies, such as polycyclic aromatic hydrocarbons, linear alkylbenzenes or pesticides, indications on the destructive potential of tsunamis (e.g., release or remobilization of anthropogenic pollutants). Further do organic anthropogenic and natural compound markers allow insights into processes during a tsunami, such as the erosion and distribution of marine and terrestrial sediment inland (inundation) and offshore (backwash).

However, the organic geochemical approach has been rarely adopted to historic and paleo-tsunami studies. We present a concept study for the application of different biological and anthropogenic organic markers to study past tsunami deposits from the Maita River Valley, Noda, Japan. At this site in northern Japan, at least 4 tsunami deposits covering the past 2700 years have been documented by different publications. This study focuses on a sediment core containing three sand layers related to paleo-tsunami events that precede the 869 CE Jogan tsunami. For the analysis of the obtained sediment core, a set of organic natural compounds including *n*-aldehydes, *n*-alkanes, terpenoids, leaf wax esters, fatty acids and fatty acid methyl esters, have been applied to differentiate between marine intrusions by historic and paleo-tsunamis from the fluvial/terrestrial background sedimentation (e.g., higher land-plant material). Aside from a characteristic natural organic signature, the tsunami deposits have been analyzed for their historic anthropogenic impact by non-industrial compounds, such as polycyclic aromatic hydrocarbons, hopanes, and fecal steroids.

For the study of historic and paleo-tsunami deposits in the sedimentary record natural organic compounds show great potential based on their high preservation potential and the insights into event-related environmental changes and processes (e.g., inundation of marine events, erosion, etc.) they allow.

Sedimentary Evidence for Paleotsunami South of the 2004 Indian Ocean Tsunami Inundation Zone

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Paleotsunami research has established that the 2004 Indian Ocean Tsunami was the most recent of at least a dozen tsunamis dating back over the past 7,400 years. It is now clear that areas devastated by the 2004 tsunami are vulnerable to future destructive events. However, there is currently no geological evidence of tsunami occurrence along the west coast of Sumatra, Indonesia south of the 2004 inundation zone. To address this, we conducted an extensive program of paleotsunami research between the city of Banda Aceh at the northern tip of Sumatra, to the city of Padang in central Sumatra. Given travel restrictions and public health concerns during the COVID-19 pandemic, we developed an innovative workflow so that researchers from multiple countries could remotely participate in field work, analysis, and local capacity building. This allowed us to core over 20 wetland sites identified as having the potential to contain buried tsunami sands. Here we present results from a wetland site approximately 40km south of the 2004 impact zone. The stratigraphy shows a sequence of sediments lain down in a brackish lagoon, which gradually became a constrained, freshwater environment. The muds are interrupted by four sandy pulses, identified by stratigraphic and grain size analysis. Foraminiferal analysis indicates an offshore marine source for the sands. These results support our interpretation of the sands as tsunami deposits. Radiocarbon dating of a peat layer below the lowest possible tsunami sand sheet dates to c. 1850 cal. yrs BP, suggesting this stretch of coast has been hit by up to four tsunamis over the past 2,000 years. These data are the first convincing evidence for paleotsunami originating from ruptures of the Sunda Megathrust south of the 2004 rupture patch, and strongly suggest that large parts of the west coast of Sumatra might be vulnerable to future tsunami.

Linking coastal boulder deposits to extreme events: Recent advances and the need for more field based datasets

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Coastal boulders and boulder fields potentially provide useful information for examining the hydraulic characteristics of tsunamis or storm waves that have struck a particular coast in the past. Boulder transport models are commonly used to reconstruct the hydraulic characteristics needed for boulder transport. Since the 1990s a suite of inverse and forward models have been applied to examine coastal boulders and boulder fields globally. The aim of such modelling commonly aims to attribute a depositional mechanism with one particular focus of modelling studies focussed on efforts to attribute tsunami or storm waves to the deposits. Inverse models can estimate the minimum wave height and velocity necessary to slide, rotate, or saltate the boulder. In contrast, forward models are used to estimate hydraulic parameters such as the maximum wave velocity or wave runup height as this is a product of the boulder transport distance. Boulder transport models commonly contain relatively few parameters because they have been developed by simplification of the overwash process. As such boulder transport models contain large errors and considerable uncertainty. Emerging fields like structure from motion (SfM) and LIDAR provide new opportunities for data collection expanding much needed data sets and increasing efficiency in the field. Current efforts to homogenise the reporting of boulder datasets are also to be applauded but there remains a clear need for field studies on boulder fields of known tsunami or storm origin. Such datasets provide validation for models and are vital for advancing efforts to better link boulder deposits with the hydrodynamic processes of storms and tsunamis.

Major controls on storm surge flooding: sea-level rise, climate or coastal landforms? Insights from the coastal sedimentary record of southern Baltic Sea

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The southern Baltic Sea coast presents an ideal target for the research on the frequency and intensity of catastrophic storm surge flooding as it is nontidal/microtidal sea, where major water level fluctuations are related to well-documented past sea-level changes and storm surge floodings. It is located in the area highly sensitive to latitudinal shifts in North Atlantic Oscillation and changes of the westerly storm tracks. Furthermore, the southern Baltic coast has recently been identified as the region where the storm surge flooding overtopping coastal barriers is one of the highest in the world and is expected to increase in the near future together with the climate change.

We document the longest to date, high-resolution sedimentary succession from the Polish coastal wetland located at Mechelinki, Puck Bay within the Gulf of Gdańsk at the southern Baltic sea coast. There, high-resolution records of extreme storm surge flooding of inundation regime within two periods: 3.6-2.9 ka BP and from ca. 0.7 ka BP until present, are preserved. The results indicate that both periods were characterized by high-frequency storm surge flooding in order of 1.3 – 4.2 events per century. They are correlated to widely recognized enhanced storminess periods in NW Europe and took place during both rising and fluctuating sea levels. Our results show that the storm surge driven coastal inundation frequency and extent largely depend on the development of coastal barriers (e.g., beach ridges).

Current research is extended to the first systematic throughout survey of locations prone/susceptible to past coastal flooding at the southern Baltic Sea in search of deposits associated with storm floods. Catastrophic historical events did not yield with substantial sedimentary record. The locations where the depositional archive of storm flooding was identified, had specific topographical, coastal and offshore bathymetric conditions, which resulted in extensive archive of multiple events.

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Cyanobacteria as potential new proxy for marine inundation events

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Storm surges and tsunamis cause temporary inundation of coastal areas, with seawater covering them for a few minutes to hours or even a few days. As a consequence, saltwater penetrates the substrate and brings moisture to otherwise dry settings.

Moreover, storm surges, storm waves and tsunami waves transport marine organic material ashore. Seaweed or seagrass may be concentrated in wrack lines, but also cover the entire flooded area. Once this organic material decomposes, nutrients are released into the environment.

Thus, marine inundation events temporarily induce increased moisture and nutrient concentrations in otherwise dry and nutrient-deprived habitats. This allows for the intermittent growth of cyanobacteria in the weeks to months after an event.

Hurricane Irma´s storm surge caused coastal flooding in the northern Caribbean in September 2017. During a post-hurricane survey on the island of Anegada (British Virgin Islands), a conspicuous bright green layer was detected in the uppermost 1-2 mm of the storm surge deposits. Morphologic and molecular analysis identified 7 different genera of cyanobacteria that colonized the fine-grained light-exposed top of the event layer. Both filamentous and coccoid forms were identified, with *Nodosilinea*, *Nostoc*, *Leptolyngbya*, *Chlorogloeopsis* and *Desikacharya* being most abundant.

During a second survey, 18 months after the hurricane, a change in color of the uppermost millimeters of the event unit was observed. The formerly green layer faded to light to medium gray. Even though less distinctive, remains of cyanobacteria were still visible under fluorescent light and under the microscope. Clearly, the conditions changed, i.e. decreased moisture and nutrient concentrations in combination with covering by wind-blown sand and thus shielding from sunlight, so that cyanobacterial growth was no longer possible.

The growth and potential conservation of cyanobacteria in the uppermost millimeters of marine inundation deposits in onshore settings may be a promising biological indicator of recent and past inundation events, and allowing for the detection of an event unit and the localization of the top of the unit.

Multi-site lacustrine sedimentary record of extreme marine inundations during the last four centuries in the southern Burin Peninsula (Newfoundland, Canada)

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The Western North Atlantic seaboard experiences various types of events causing extreme marine inundations (EMIs), including winter storms, tsunamis, and hurricanes. This study aims to provide the first lake-sediment-based reconstruction of recent EMI history (past ~350 years) of the southern Burin Peninsula (Newfoundland, Canada). We investigated short sediment cores collected from four shallow coastal lakes. The identification of EMIs relied mainly on sand grain counts supported by the analyzes of diatoms, dry bulk density, and loss-on-ignition. The age-depth models of the cores were based on ^{210}Pb and ^{137}Cs dating. Correlation of our records with historical events confirmed that statistically significant sand count peaks serve as a useful proxy for EMIs in the case of three of the sites. Diatom composition did not reveal noticeable turnover at depths corresponding to EMIs at any of the four sites, likely because diatom communities in the lakes are adapted to salinity fluctuations due to the frequent minor marine water overtopping events. Combined, the four records indicated that at least seven EMIs occurred over the last ~350 years, four of which could be likely correlated with historically documented events, namely the 1755 Lisbon tsunami, the 1775 Great Independence Hurricane, the 1929 Newfoundland tsunami and the 1983 winter storm. The observed recurrence of EMIs resembles the coastal flooding frequency along the subtropical western North Atlantic seaboard. However, the criteria to identify the cause of particular EMI events still need to be established. The study was financed through a grant from the National Science Centre (NCN), Grant No. 2020/37/N/ST10/02614.

Portuguese offshore tsunami deposits - high-resolution X-ray CT-scans as an innovative analytical tool

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X-ray Computed Tomography (XCT) is a powerful tool for sedimentological studies. It is a non-destructive imaging technique that allows the characterization of sediments and the identification of sedimentary structures. Microstructures and sedimentary fabric can be analysed in 3D. High-resolution XCT-scans unequivocally contribute to raising the understanding of tsunami deposits and their micromorphological imprints, and establishing their relationship with flow dynamics of both the inundation and backwash phases.
We present high-resolution XCT-scans of shallow offshore sediment cores collected from the southwestern Portuguese Algarve shelf, focussing on sedimentary signatures of two tsunami deposits, related to the 1755 CE Lisbon event and an older event dated to ca. 3400 years BP. XCT-scans of both offshore tsunami deposits were performed in 50 µm and 20 µm per voxel resolution. Selected sections were sub-sampled to achieve a higher resolution of up to 14 µm per voxel. The 1755 CE tsunami deposits consist of shell fragments and sand-sized quartz grains mixed with fine-grained particles (mean grain-size of silt to very fine sand) representing the present-day permanent sedimentation regime of this shelf region. The ca. 3400 years BP tsunami deposits are much more complex with peculiar characteristics in different sub-units. An erosive base is followed upwards by a thin lamina enriched in shell fragments and an inversely graded sand lamina. Further up-section, the deposit consists of well-sorted quartz-rich medium sand that is affected atop by another erosive surface. The latter is followed by fine-grained background sediments mixed with shell fragments and sand-sized quartz grains. The characteristics of the uppermost sub-unit and the 1755 CE tsunami deposit are quite comparable. We present the results of semi-automated image analysis for the characterisation of the samples in 2D and 3D. The 2D analysis determined grain-size parameters. The 3D analysis revealed the properties of the sedimentary fabric. Both provide clues to infer flow characteristics, such as flow regime, current strength and sediment concentration.

Session 181: Transferring scientific knowledge on Quaternary geological processes and geohazards into disaster risk reduction activities

Palaeo-activity of large, deep-seated landslides in the Whanganui-Rangitikei Hill Country, New Zealand

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Large, deep-seated landslides are a prominent geomorphological feature of Quaternary landscapes globally, and in New Zealand, with >7000 such landslides mapped to date. Many of these are situated within Neogene-aged marine sedimentary soft rocks that cover ~15% of the country. These large (>2 ha) landslides can be hazardous; while typically slow-moving (mm – m per year), cumulative displacements can damage land and infrastructure, but they can also fail rapidly. They are a key agent of hillslope erosion and source of sediments to river systems. Few of the known landslides have been dated, limiting our ability to assess failure patterns and changes in sediment delivery over time. Our current research aims to narrow this knowledge gap by dating soft-rock landslides in the Whanganui/ Rangitikei Hill Country. In particular, our objective is to assess the long-term patterns of failure, and rates of sediment delivery within soft-rock terrain, to help contextualize modern day patterns and sediment delivery rates.

Our primary method of absolute age dating is radiocarbon analysis of organic matter accumulated within landslide deposit depressions, with samples recovered by coring. We date 10-15 landslides and use these ages to calibrate a morphometric dating tool we are developing, which quantifies landslide age (i.e., youthfulness of the morphological expression) from high-resolution elevation data. The first step in tool development involves statistical modelling of the relationship between multiple morphometric variables and the ages of several dated landslides. In the second step, we test the model's performance against landslides independent of the model training set. In the final step, we apply the tool to landslides across the whole study region.

Herein we present preliminary results of the morphometric dating tool development, and absolute age data for several landslides within the Mangawhero catchment in the central North Island of New Zealand. We use the data from our study to investigate links between landslide age and activity in relation to external factors, which can be used to guide land and hazard management decisions and inform erosion control.

Pockmark Assessment on the Mediterranean Continental Margins

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Fluids (gas and liquids) trapped within sedimentary strata being lighter than the solids, move upwards driven by buoyancy. The seafloor “fluid flow” is widely recognised in different geodynamic contexts (e.g., active and rifted continental margins, compression zones -subductions-, highly sedimented areas -deltas), and gives rise to different morphologies. Pockmarks (known since the ‘70s) are the most common features linked to fluid escaping from the seafloor and are characterised by a negative relief. They can have diameters and depths of up to a few kms and >100m respectively, with circular to elongate planforms, and flat bottom to conical vertical profiles. The general mechanisms for pockmark formation and growth are still not completely understood even though geological and geophysical data provide valuable insights on factors controlling their genesis and development. Several hypotheses and conceptual models have been proposed to explain the formation and maintenance of pockmarks (e.g., by near-bottom currents), which involve either continuous processes (seeps) or rapid and sudden events of episodic releases and blowout (vents) of fluids. Pockmarks are often found associated with fluid-driven sedimentary failures. Their occurrence can be considered as an important revealing geohazard factor that suggests the presence of fluid migration, excess pore pressure and their potential relationship for the triggering of landslides. Therefore, their study is important for geohazard assessment and to setup any submarine infrastructure. Several studies also suggest pockmarks are important earthquake precursors, as it has been noted increase of seeping water temperature before the seismic event and still venting of gas bubbles afterward. The correlation between fluids and seismic activity is rather reasonable since fluids tend to act as a lubricant in faults. Many Mediterranean regions, from the Alboran Sea to the Levantine Basin host large pockmark fields. In this study we selected more than ~7,500 pockmarks to evaluate (i) their relationship with all the potential factors driving their formation based on morphological, sedimentological, and geochemical evidences (e.g., seafloor features, active faults, hydrocarbon regions, gas hydrates), and (ii) their likelihood of occurrence across the whole Mediterranean Continental Margins on a GIS-based and data-driven approaches.

Geomorphological education to students and citizens for disaster risk reduction

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Reducing the risks of natural disasters is crucial for the sustainable development of nations and societies. Island arcs are prone to various types of natural disasters due to their tectonic settings and maritime environments. For example, intense rainfall, heavy snow, earthquakes, tsunamis, and volcanic eruptions often affect Japan, resulting in casualties and economic losses. In such places, practical education on natural disasters for ordinary people, based on scientific knowledge, is an essential task of relevant scientists such as physical geographers and earth scientists.

Therefore, we have developed educational materials and modules on geomorphology and natural disasters. We have used them in classes and social events for high-school students, university undergraduates, and citizens in Japan and China. The materials are in digital format utilizing GIS, Internet technology, and augmented reality. The developed materials include 1) online resources for learning GIS operations, including geomorphometric analysis; 2) Web-based online GIS for a better understanding of flood hazard maps in relation to landforms; and 3) explanatory materials of typical landforms in Japan based on photographs and topographic data obtained by drones, along with original text and illustrations.

This presentation introduces the main points of our educational activities, discusses their implications, and provides future perspectives. The questionnaire surveys on the attendees of classes and social events allowed us to understand the effectiveness of our education. We have found that the developed digital educational materials with functions of changing map layers and 3D topographic representation are more effective than traditional analog materials, such as paper hazard maps. For example, young high-school students effectively operated the digital system to identify possible flood-inundation areas and correctly select evacuation routes. In contrast, understanding some geomorphological issues, such as recognizing disaster-prone landform types on a map or photograph, was challenging for them. We will update the educational materials and modules considering the limitations of the current version and evaluate the effectiveness of new versions through applications in classes and events.

GIS based Regional Approach on Landslide Hazard Assessment in Karewa Basin, Jammu and Kashmir, India

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Landslides are one of the biggest natural disasters occurring in every part of the world. In India, land sliding is the second largest catastrophe, affecting thousands of people annually. This disaster is often connected with heavy rainfall events and active tectonics of the Himalayas. Considering the mountainous region, the events are aided by the steeper slope morphometry, undercutting by rivers, and numerous mega infrastructure projects being sanctioned in the Himalayas. A lot of studies have been carried out on landslides and several attempts have been made in predicting them. Landslide forecasting with certainty is still a challenge in the Himalayas. The present study focuses on remote sensing and GIS-based regional approach on Landslide Hazard Assessment in Karewa Basin, Jammu and Kashmir, India. The intermontane Karewa basin covering an area of 11717.86 square kilometers lies between the Great Himalayan Range to the northeast and Pir-Panjal Range to the southwest. The basin is tectonically active with Panjal and Main Boundary thrust running across the length of the basin in the Southwest and Zanskar thrust in the North East. The goal of the current study is to determine and characterize the crucial topographical parameters that influence the frequency of landslides in the area. Topographic maps, on-site observations, and available published data are used, and the corresponding thematic data layers are created in the GIS domain. Also, the satellite data, HRDEM, and Landsat series 8 OLI/TIRS level 2 atmospheric corrected data are utilized for the Landslide Hazard assessment of the area using weighed overlay approach. The result of the study is presented in the form of Hazard maps and the study area is divided into five different hazard zones based on their potential of land sliding in the future. The resulting maps can be used as a primary source of comprehensive evaluation of landslide hazards in the area with certain modifications as per the requirements.

Holocene Drought processes, community risk perception, and preparedness in Wyoming headwaters

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Holocene climate change has and will continue to increase environmental hazards (e.g. droughts), with impacts on vulnerable, rural and minoritized populations. In the Western U.S., impacts to water resources exemplify an environmental hazard enhanced by climate change during the Holocene. Within the region, Wyoming has a unique geographic backdrop that includes headwaters of three major river basins (Snake/Columbia, Green/Colorado, and Platte/Mississippi), with associated rural communities. Anthropogenic warming during the Holocene has led to early spring melt, reduced runoff, and diminished late-season flow. This research focuses on the spatial and temporal variability of atmospheric processes associated with recent droughts impacting Wyoming's headwater regions. We identified recent anomalous dry years from precipitation time series and used data from the ERA5 project to analyze climate variables associated with precipitation processes during selected dry years. Seasonal composite anomalies were calculated for precipitation rate; specific humidity at 850hPa; geopotential height at 500hPa; and omega at 500hPa. The composite-anomaly values represent the selected cases (e.g. drought years) compared to long-term means (e.g. average conditions) to provide information on atmospheric processes associated with persistent drought conditions in the region. Preliminary results indicate that anomalous dry conditions are supported by persistent sinking motions (omega at 500hPa), lower-than-normal moisture availability (indicated by specific humidity at 850hPa) combined with anomalous higher-than-normal pressure regionally. Our results use modern climate data to understand drought processes that can be applied to paleo-environmental, present, and future hazards. We use our results from our climate analysis of recent drought, as well as future temperatures from CMIP5 data, to develop graphics for use in community-based focus groups to assess community members' perception of past and future drought risk. Holocene climate change (e.g. enhanced drought) both recent and future will impact communities regionally. Through coding responses from community-member focus groups, we use analysis of variance; and cluster analysis for individual basins and between basins to identify community perception of drought risk. Our research provides a bridge between Holocene climate processes and perceived risk within rural communities to assist in the development of community preparedness to extreme events like drought.

Exploiting inventories of submarine geohazard-related features as a tool for a first assessment of coastal susceptibility to marine geohazard: examples from Calabro-Tyrrhenian margin, Messina Strait and Aeolian islands.

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In the last few decades, a large effort in mapping continental margins and submarine flanks of coastal/insular volcanoes was performed at worldwide scale through the ongoing advances in seafloor imagery systems (especially using vessel- and/or AUV/ROV-mounted multibeam systems). These data have drastically changed our vision of the geological processes shaping the seafloor, also evidencing a large suite of possible geohazard-related features, including submarine landslides and canyons, pockmarks, active fault scarps, migrating bedforms, volcanic cones. In Italy, the Department of Civil Protection (DPC) funded a large-scale project (2007-2013 MaGIC Project) devoted to collect multibeam data along most of the Italian margins, through which mapping the main geohazard-related features here present. Just as an example, more than 8,000 landslide scars were mapped together with hundreds of submarine canyons, some of them deeply indenting the continental shelf up to arrive to the coast.

In order to let the study became an operational instrument, this large dataset was re-classified and partially re-analysed to provide a useful tool for civil protection purposes. The hazard zoning of coastline according to susceptibility to geological processes able to potentially generate marine geohazards was realised, including submarine eruption, fluid seepage, retrogressive erosion at canyon's head, mass wasting processes with the generation of local tsunami waves.

In this work, we briefly show a first and general approach based on the presence/absence of geohazard-related features for a preliminary zoning at regional scale. Then, we illustrate a more advanced approach, based on the re-analysis of morpho-bathymetric data integrated with simple tsunami modelling on specific areas, such as part of the Calabro-Tyrrhenian margin, the Messina Strait and some volcanic edifices of the Aeolian Arc.

Session 182: From Cores to Code: Data-Model Integration to Improve Reconstructions and Forecasts of Coastal Change

Onshore deposit sedimentology and source mechanism of the 1994 Mindoro tsunami in the Philippines

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The 1994 Mindoro tsunami is the most recent of destructive tsunamis in the Philippines, producing wave heights at shore exceeding 7 m and resulting in 41 deaths. The tsunami hit the coasts surrounding the Verde Island Passage (VIP) following a Mw 7.1 earthquake along the right-lateral Aglubang River Fault. While local in scale, the 1994 tsunami holds global significance as one of the few known examples of tsunamis occurring after strike-slip earthquakes, similar to the 2018 Sulawesi tsunami in Indonesia.
Submarine geomorphological mapping of the VIP resulted in the discovery of the San Andres submarine mass failure (SASMF). The SASMF, located <1 km north of San Andres, has an estimated volume of 0.0483 km^3. Analysis of pre-1956 depth soundings and post-1997 submarine surveys constrains its possible occurrence between 1956 and 1997. Assuming that the SASMF was triggered by the Mw 7.1 earthquake, numerical modeling of the 1994 tsunami based on a combined earthquake and SMF source (EQ+SMF) mechanism approximates actual wave height measurements better than an earthquake-only source mechanism (EQ-only). Compared with observed wave heights at shore, root mean square errors of modeled median wave heights for the EQ-only and EQ+SMF models are 3.21 m and 1.6 m, respectively.
Two facies of the onshore 1994 tsunami deposit were also identified from geoslicer sampling in northern Oriental Mindoro in February 2019. The tsunami deposit in San Teodoro, 6 km WSW of SASMF and 20 m inland, occurs as >80 cm-thick channel-fill sediments composed of normally-graded, medium-to-coarse lithic sand with a basal pebble-rich layer. At least 2 wave incursions are recognized based on the occurrence of an intermediary, □1 cm-thick mud cap. In Baco, <1 km S of SASMF, the tsunami deposit is characterized by a □25 cm-thick layer of mud clast-rich, muddy, medium-to-coarse lithic sand with a basal erosional contact over mangrove swamp sediments. Radiocarbon dating of the mud clast yielded an age between 843 and 790 BC. Modeled wave velocities at the Baco sampling site exceed 3 m/s, which could explain the inclusion of old mud layers within the tsunami deposit.

End-member mixing analysis (EMMA) as a novel tool for the detection of paleo-storms in far inland lake sediment records

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Major tropical cyclones and other large storm events cause extensive damage in coastal regions throughout the western North Atlantic Basin. The short instrumental record leaves significant gaps in understanding long-term trends in TC recurrence and intensity, creating uncertainty about modeling future storm trends. Analysis of a >500-year core record from Harvey Lake, located >80 km from the Atlantic coast in southwestern New Brunswick, Canada was carried out using: 1) End Member Mixing Analysis (EMMA) of lake sediment grain size data to identify storm-linked sedimentological processes; and 2) ITRAX XRF derived element/ratios (Fe, Ti, Ca/Sr, Zr/Rb, K/Rb, Br+Cl/Al) associated with precipitation, weathering, catchment runoff and air masses. Three derived end members were correlated to heavy rainfall events (EM01), spring freshet (EM02), and large storm events (EM03). CONISS analysis of the EMMA and XRF core data resulted in recognition of four unique climatic zones distinguished by distinct distributions of storm records and rainfall, weathering, runoff, and air masses. Numerous, major (EM01) rainfall events and (EM03) large storm events characterized the basal core record during the early Little Ice Age (LIAa; Zone 1) phase, terminating at ~1645. A near cessation of heavy rainfall and major events differentiated the subsequent colder LIAb (~1645-1825; Zone 2) and subsequent Little Ice Age Transition (~1825-1895; Zone 3) . A resurgence of major rainfall and large storm events occurred during recovery from the LIA starting in ~1895 (Zone 4). EMMA provides a robust tool for recognition of large stormu and major rainfall events, and greatly expands the potential for paleo-storm activity research well inland from coastal regions.

The past, present, and future of barrier-system dynamics: New insights from the Virginia Barrier Islands (USA)

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Among the most dynamic coastal landforms, barrier islands play central roles in ecosystem processes, habitat resilience, and mainland storm protection. Though over centennial and longer periods barriers simply migrate landward in near-direct proportion to the rate of sea-level rise (SLR), mesoscale barrier morphodynamics are far more complex. Focusing on the 13 largely undeveloped barrier islands of Virginia's Eastern Shore (USA), we combine new insights from the late Holocene geologic record, historical data, and numerical modeling to explore multidecadal to centennial barrier-system behavior. Specifically, we document shifts between phases of island erosion, migration, and progradation in response to changing rates of SLR, storminess, interactions with antecedent substrate, and long- and cross-shore sand exchanges. Overall, we find that the Virginia Barrier Islands have modestly (<5%) decreased in volume over historical time, with average shoreline transgression rates (due to island narrowing or landward migration) accelerating by ~45% in the last ~100 years. Given that the local SLR rate has increased by ≥200% over this same period, we infer multidecadal lag dynamics in barrier behavior with respect to SLR. Using a novel coastal evolution model, we reveal that observed shoreline retreat at the barrier-chain scale is not controlled by SLR over the last decades, but rather by the baseline SLR rate of the past centuries. As such, we predict a "committed" coastal response: the rate of retreat of undeveloped barriers will increase by ~50% within the next century, even if SLR remains at present rates. At the island scale, these dynamics play out in a far more complex manner: the potential for retreat is first realized through removal of 'geomorphic capital' (sand reservoirs associated with island stratigraphy, dune systems, tidal deltas, etc.), which can accelerate sand delivery to downdrift islands. Initiation of net migration once the eroding island becomes overwash-dominated, leads to an acceleration in shoreline migration and in the erosion of the downdrift islands, which are now experiencing a decreased (or net negative) longshore sand flux. Together, these findings help elucidate and better predict barrier behaviors, including those active through inter-island sand exchanges, over long coastal reaches, and with significant lag dynamics.

Reconstructing the Extent of the 1964 Alaska Tsunami at Port Alberni and Ucluelet, British Columbia, Canada: Implications for the Salinization of Groundwater Resources in Northern Cascadia

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An important, but often underestimated, consequence of tsunami inundation on a coastline is the salinization of groundwater-bearing geologic formations known as aquifers. Tsunami-related salinization may yield groundwater unusable for up to 15 years. Key variables of uncertainty related to the effects of tsunamis on groundwater include tsunami flow depth and the rate at which water can pass through site-specific geologic material. Thus, this problem requires methodologies from both the paleoseismological and hydrogeological disciplines. We seek to improve our understanding of the impacts of far-field tsunamis on northern Cascadia, and to quantify the risk they pose to groundwater resources in the coastal communities of Port Alberni and Ucluelet, located on western Vancouver Island, British Columbia, Canada. We focus on the most recent far-field tsunami in the region known to have inundated both locations – the 1964 Alaska tsunami. A framework for assessing the risk of tsunami-groundwater contamination is developed using sedimentological analysis (stratigraphic mapping, grain size analysis, short-lived isotope dating) and groundwater modeling. To accomplish this goal, we use sedimentary evidence and grain-size distributions associated with the 1964 tsunami deposit to reconstruct the wave characteristics. Using a Russian peat corer, 50 cm-long cores were collected from two marsh locations in Port Alberni (19 cores) and Ucluelet (4 cores). Laser diffraction grain-size analysis on each core reveals that the 1964 tsunami sand deposit consists of 1 to 5 cm-thick layers of very fine to medium grained (ranging 4.87 to 2.20 ϕ), normally graded sand varying in depth from 5 to 18 cm below ground surface. Combined Cs-137 and Pb-210 dating confirm that sampled sands likely derive from 1964. These data and a high-resolution digital surface model derived from LiDAR are combined in an inverse sediment transport model (TSUFLIND) to resolve geologically-constrained inundation maps. Impacts of the 1964 tsunami inundation on groundwater resources are assessed using a hydrogeological model that can account for saturated-unsaturated and variable-density flow (SUTRA). Aquifer risk maps for each community will combine groundwater and tsunami inundation modelling results to provide vital information for at-risk communities in the region seeking to protect their groundwater supply.

Sedimentary records of high-energy events in the coastal lake of Arenella (South-eastern Sicily, Italy)

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Past occurrences of tsunami and storm events can leave imprints in the sedimentary records located along the coasts of Mediterranean coast. Storm and tsunami impacts determine the sedimentation of high-energy deposits in coastal areas. In particular, lagoons and backdune areas constitute long-term Holocene records. South-eastern Sicily is one of the most seismically active areas of the Mediterranean Sea, characterized by a high level of crustal seismicity, causing major earthquakes (up to Mw ~7). As a consequence, this area is prone to earthquake-generated tsunamis, which affected the Ionian coast of Sicily in historical times. These tsunamis left geomorphic and sedimentary imprints, such as large boulders or high-energy deposits, along the coasts. In this study, we describe several sediment cores sampled in a costal lake sited 30 km southward the town of Siracusa. This lake is located about 100m from the coastline and, as described in ancient charts and chronicles, it has never been connected with the sea. In 2014 and 2018 two different Mediterranean Hurricanes (Quendresa and Zorbas respectively) flooded the coastal area reaching the lake and depositing thick layers of coarse sand. Several cores have been from the lake, sediments result mainly represented by silty peat deposits interbedded with various sandy marine layers. Marine layers are overlaid by wood fragments, which were dated through radiocarbon method to provide temporal constraints on the high-energy deposits. Radiocarbon dating show that the upper marine layer can be temporally assigned to the 1908 tsunami event while the lower marine layer can be attributed to the 1693 tsunami event. These two events were particularly destructive and led to coastal flooding along the coast of South-eastern Sicily. Several analyses have been performed in order to better define the characteristics of the 1908 and 1693 tsunami events and to identify other marine extreme events that reached the lake in historical times, with particular focus on events that have occurred since 1908.

Session 183: Frontiers in drylands research

Najaf Sea palaeoshorelines, western Iraq

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Investigation of palaeolake deposits in arid and semi-arid regions is important for determining the palaeohydrological conditions that imposed controls on human communities throughout antiquity. This is particularly important in Iraq where many early civilisations were located. Resolving this debate is critical because freshwater availability would have been vital for local populations and the development of agriculture in the early to mid Holocene. Ephemeral lakes in Iraq have the potential to make a useful contribution to these debates by providing data for the north of the Arabian Peninsula. They also provide a useful background context for current climate changes.

Between the Mesopotamian floodplain in the centre of Iraq and the western desert on the western border are a series of north-west to south-east aligned depositional basins which currently contain ephemeral lakes of varying sizes (Habaniyah, Razazza, Najaf, Sawa). These follow the line of the Abu-Jir-Euphrates fault zone and are fed by a series of wadis aligned across the desert from the southwest. Prior to the tectonic uplift that created these depressions, these wadis fed large fans. Whilst there is evidence of prehistoric cave dwelling in the natural caves formed in the Injana Formation that underlies the fan deposits, there is no direct age control on the fan deposits or the initial formation of these basins. It is therefore not known when these depressions began to fill with water and whether lake volumes have been greater in the past. The Najaf Sea has in recent memory been completely dry (1980s, satellite images). To the east of Najaf Sea, detailed investigation and radiocarbon dating of palaeochannels of the Euphrates has shown that the Euphrates river flowed close to this depression from 125 BC to 1258 AD (Jotheri et al., 2016).

In this project we date previous extents of the Najaf Sea, shown in palaeoshorelines. This paper will present the context and importance of the Najaf Sea and OSL and radiocarbon dated sequences including heavy mineral and fossil shell data from both palaeoshorelines and boreholes drilled in a former channel that connected the Najaf Sea to the Euphrates. Regional palaeogeographies will be reconstructed.

Implications for Late Quaternary climate, weathering, and soil formation at Atacama's hyperarid coast drawn from trapped charge- and cosmogenic nuclide-dated alluvial fans

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The limited availability of water in the hyperarid Atacama Desert governs the occurrence and magnitude of hydromorphodynamic events, subsequent formation of fluvial and alluvial landforms, biotic activity, weathering, and soil formation. While those aspects have received considerable attention by geoscientists in the core of the desert, they are as yet not well understood especially in the coastal environment. In contrast to the interior, the coast receives much larger amounts of moisture – partly due to slightly higher precipitation but mainly as a result of orographic blocking of advective fog by the Coastal Cordillera between ~500 and ~1,200 m above sea level.

We present a synthesis of six years of research on the coastal alluvial fans of the Atacama Desert (20.5–25.5°S), conducted within the framework of the CRC 1211 "Earth – Evolution at the dry limit", and provide new insights into the processes and timing of their primary aggradation as well as secondary, post-depositional alteration by weathering and pedogenesis. Therefore, we established a regional geochronological framework based on both trapped charge dating (K-feldspar luminescence and electron spin resonance) and cosmogenic ^{10}Be exposure dating. The latter was additionally applied for chronosequence studies on two specific multi-stage alluvial fans. Combining the morphochronologies with a morphostratigraphy (spectral, textural, and gravelometric surface characteristics) on the one hand, and a pedostratigraphy (physicochemical soil properties) on the other, allowed to deduce the types and rates of weathering and soil formation, respectively.

Our results indicate that increased fan aggradation occurred throughout Late Pleistocene and Holocene periods of higher pluvial activity nourished by the Pacific, while fan generations older than the last interglacial period are absent or only preserved in form of small remnants. Post-depositional formation of weathering rinds, clast breakdown due to salt weathering, and denudation results over timescales of 10^4 years in mature desert pavements. The weathering intensity during the Late Quaternary is found to be related to sea surface temperature variability and sea level variations jointly driving the oceanic moisture supply. Towards the south, higher (palaeo)precipitation resulted in more advanced soil formation characterized by initial humification, decalcification closely coupled with acidification, rubification, and loamification.

Age and origin of gravel spreads in the Thar Desert, India

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The presence of fluvial gravels in the core of the Thar desert has been enigmatic and their origin has been widely debated. The gravels form a lag - a layer of gravel with little or no matrix. They are poorly sorted, subrounded to rounded pebbles of 1-80 cm in size. Conjectures about the origin of the gravels include fluvial transport during the early Quaternary or weathering of conglomerate in Mesozoic rocks. The age of lag formation is unknown. To resolve the origin of the gravels and the timing of the lag formation, we (a) used high resolution satellite images to re-map gravel occurrences and their contexts, (b) sampled major gravel occurrences at Bhojka, Hamira, Jayal, and Solanki sites along with their source rocks and, (c) measured in-situ produced cosmogenic nuclides to establish when the lag appeared. A major occurrence of gravel of > 50 km^2 is at the Bhojka site near Jaisalmer. Field evidence buttresses the suggestion that the gravels are the weathered products of underlying conglomeratic bedrock near Jaisalmer, Bikaner-Nagaur and Barmer in basins of Mesozoic age.
Initial ^{10}Be measurements suggest exposure ages of 0.7 to 1.7 Ma for gravels at Bhojka, Hamira Jayal, and Solanki. These ages are consistent with the archaeological evidence of a pre-Acheulian age. Depth profile of ^{10}Be at Bhojka suggests that the landscape was stable during most of the mid-late Quaternary and perhaps even longer. Currently ^{26}Al measurements are underway on quartzite pebbles and these together with other measures will inform complexities (if any) about putative overburden on the lag gravel. Owing to the fact that ^{21}Ne is a stable nuclide, its concentration together with appropriate modelling should provide an upper bound to the age and potentially help resolve the debate about the origin of these gravels.
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A mechanistic approach for interpreting hydroclimate from halite-bearing sediments during abrupt climatic transitions

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Establishing accurate paleo-hydroclimatic reconstructions from lacustrine and marine archives is a long-standing challenge in paleoenvironment studies. Closed-basin evaporites and especially halite record episodes of extremely arid conditions during rapid climate change. However, the complex limnologic behavior of deep hypersaline water bodies and the stochastic hydroclimatic regime and its variations limit detailed paleo-hydroclimatic interpretations from such records. Therefore, we developed a mass-balance model to explore hydrology-limnology-sedimentology relationships in hypersaline environments under both deterministic and stochastic approaches that generate synthetic halite-mud sequences. Applying the model to the Holocene Dead Sea halites yields novel insights on paleoenvironmental conditions in the Levant, a hydroclimatically sensitive region, on the boarder between the mid-latitude and the arid climate zones. The deterministic framework indicates that (i) under a series of similar hydroclimatic cycles, the thickness of each subsequent halite interval decreases, due to the depletion of dissolved ions storage in the brine. (ii) Halite deposition requires lake levels drop to below the minimal lake level of the preceding cycle. (iii) The time interval between halite deposition and the hydrologic minimum is increasingly delayed in subsequent cycles. Thus, counter-intuitively, halite deposition mostly takes place as water discharge increases, providing that the water balance is still negative. The stochastic approach produced random sequences comparable to the observed Dead Sea sedimentary record. It demonstrates that some hydrologic minima are not represented by halite deposition at all. Furthermore, the thickness and number of halite beds at each hydrologic cycle vary substantially, depending on the specific hydrologic conditions realized. Finally, our results imply that the major deglaciation, pre-Holocene (~14 ka BP) Dead Sea level drop, previously assumed to be a record minimum, could not have been as pronounced as suggested, and must have been milder than the subsequent drop at the early Holocene (~11–10 ka BP).

The challenges of dating (and interpreting) dunes in topographically-complex regions – a case study from the Mojave Desert

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The dunes of the Mojave River catchment have been studied in some detail over the last three decades, particularly in terms of their relationship to the region's basin and range topography ("sand-transport corridors"), and sediment supply variability linked to the evolution of the Mojave River. There are however, reasons to suggest existing luminescence chronologies for these deposits need to be re-assessed. In particular, quartz may regularly exhibit malign luminescence properties, while low temperature K-feldspar IRSL suffers from relatively high anomalous fading rates. We applied post-IR IRSL methods to a suite of new luminescence samples from a range of Mojave aeolian deposits. We specifically considered sands associated with complex topography (The Cady Mountains) abutting the Mojave River and (palaeo) Lake Manix. The goal was to interrogate the proposition that topographically complex environments strongly mediate the (local) potential to store sand. Such control will greatly complicate interpretations of any "aeolian record" obtained from (e.g.) a multi-site programme of OSL dating. Sand deposits in the Cady Mountains were analysed using the Landserf morphometric classification GIS, and were shown to be represented by four accommodation space types: Slopes (mountain front sand ramps), Valley-Fills, Sandsheets and Slope-Valley-Fill composites. Luminescence samples were obtained from exemplars of each.

K-feldspar post-IR IRSL dating protocols perform very well, although incomplete bleaching remains a hazard where aeolian and slope-derived sediments mix (e.g. within some sand ramps). Our new ages span ~90 ka and differ with accommodation space type. Sand ramps consistently represent the oldest deposits (~40-80 ka), while (early-mid) Holocene dune accumulation is particularly associated with Sandsheets and Valley-Fills, both on the margins and within the interior of the mountain block. The results suggest topography significantly mediates the preserved aeolian sedimentary history, due to varied trapping potential, distances to sediment source and preservation potential (e.g. potential overland flow). The ages differ from previously compiled (mostly sand ramp) data, but this need not only reflect age inaccuracy. The preserved record at any locale is likely to be highly contingent on its meso-scale topographic setting. This renders the climatic / environmental interpretation of OSL ages/phases compiled across multiple sites questionable.

New constraints on the glacial–interglacial paleohydrology of southwestern North America from lake and wetland deposits at Playa San Bartolo, northwest Mexico

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During the last glacial–interglacial transition (ca. 18–11 ka), millennial-scale shifts in global atmospheric-oceanic circulation resulted in highly variable hydrologic responses across southwestern North America. Regional paleohydrologic records are critical to resolving these spatial and temporal shifts in patterns of moisture transport and for understanding the dominant mechanisms driving past changes in the magnitude, seasonality, and timing of precipitation. Here, we present new constraints on the paleohydrology of southwestern North America from Playa San Bartolo, a 42-km^2 intermittently flooded shallow basin in Sonora, northwest Mexico. As one of the most southerly lake systems in southwestern North America, in a region influenced by both winter westerly and summer monsoon precipitation, Playa San Bartolo is an important archive for understanding the regional response of the arid Southwest to late Quaternary climate change. We reconstruct the expansion and contraction of lake and wetland environments based on the sedimentology and stratigraphy as well as the fossil and stable isotope composition of lacustrine and groundwater discharge deposits exposed in outcrop. Radiocarbon determinations on fossil gastropod shells and sediment total organic carbon suggest that elevated lake levels coincided with the Last Glacial Maximum (~20 ka) and Heinrich Event 1 (~16 ka). From ~18–16 ka, an interval of decreased effective moisture throughout the southwestern US, a shallow lake and wetlands persisted at Playa San Bartolo, perhaps due to intensification of the North American monsoon. A shift from lacustrine to groundwater-discharge-dominated deposition and playa-like conditions characterizes the early–middle Holocene. By ca. 6 ka, desiccation and wind erosion of the basin floor resulted in the emplacement of a large source-bordering dune. The Playa San Bartolo record is broadly consistent with the southernmost pluvial lakes in the southwestern US, which, together, indicate that the dominant factor affecting moisture availability are shifts in Northern Hemisphere subtropical and midlatitude circulation systems influenced by the extent of the Laurentide Ice Sheet and abrupt freshwater input into the North Atlantic during Heinrich Events.

Extreme pluvials over the last two millennia detected using ephemeral lakes

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The Australian continent is characterised by thousands of ephemeral lakes that only fill after extreme (daily or seasonal maxima) rainfall conditions. Many have little to no contributing/catchment area, while others drain up to one seventh of the continent (e.g. Kati Thanda-Lake Eyre [KT-LE], draining 1.14 M km^2). Here we use ephemeral lakes from diverse moisture sources across the Australian continent and with catchment areas varying over three orders of magnitude to reconstruct past pluvial phases over the last two millennia. We present chrono-stratigraphic data of beaches/palaeoshorelines that are all at or above the modern maximum (e.g. ≥ 1% annual exceedance probability), therefore representing extreme runoff conditions. Such landforms represent unambiguous evidence of pluvials that have occurred over the last 2000 years. Data from Lake Woods (Northern Territory), Kati Thanda-Lake Eyre, Lake George (NSW) and Lake Buchanan (Queensland) are discussed with the aim of assessing recurrence intervals for such wet extremes. These sedimentary archives, whilst discontinuous, add to the capacity to evaluate late Holocene climate change and extreme rainfall event occurrence within context of the observational record.

Windows of opportunity: the role of Arabia as a biogeographic crossroad over the Plio-Pleistocene

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Arabia is part of the largest near-continuous chain of drylands stretching from the Sahara to the Gobi Desert. This harsh and often hyper-arid belt acts as a barrier between two major biogeographic realms: the Palearctic and the Afrotropics, creating unique geographic endemism between Africa and Eurasia. However, late Mid- to Late Pleistocene hydroclimate records in Arabia suggest significant humid periods evidenced by paleolakes in the Nefud Desert and the Empty Quarter (the largest sand desert on Earth) associated with vertebrate fossils and stone tool assemblages. In coastal southern Arabia speleothem evidence also suggests the occurrences of humid periods in conjunction with insolation-driven interglacial phases. However, there are no direct hydroclimate records from the hyper-arid interior, particularly before the mid-Pleistocene, leaving the terrestrial hydroclimate and the role of Arabia as a biogeographic crossroads, largely unknown.
We use desert speleothems preserved in northern Arabian caves to identify past humid phases. These are particularly useful terrestrial climate archives as they act as underground rain gauges, requiring a minimum of ~300 mm a^{-1} precipitation, pedogenesis and vegetation cover to form. Moreover, they can be accurately and precisely dated and are subsequently a valuable tool in identifying past large-scale hydrological and vegetation changes in ancient drylands. Here, we show evidence for multiple 'windows of opportunity' over the Plio-Pleistocene which contain multiple episodes of climate amelioration, allowing biogeographic exchange and dispersals to occur across the Arabian hyper-arid zone. Further, the isotopic composition ($d^{18}O$ and $d^{2}H$) of speleothem fluid inclusion waters, representing 'fossil rainwater', reveal the changing influence of tropical rain-belt precipitation in Arabia across Earth's transition from a largely 'ice-free' northern hemisphere to an 'ice-age' world. These results have significant implications for understanding the drivers of dryland aridity in non-polar deserts globally.

Session 184: Seismic hazard assessment in populated areas of Latin America: incorporating seismogenic faults

Potential seismogenic structures in populated areas of NW Argentina: the Medeiros anticline and the growing capital of Salta province

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Historical and instrumental seismicity records from the Central Andes of north-western Argentina spanning the last 350 years has been the primary data source to characterize this region’s exposure to seismic hazard as “moderate” to “high” (0.18-0.25 PGA). The lack of detailed studies regarding widespread evidence of Quaternary seismogenic deformation has prevented a more accurate seismic hazard assessment (SHA) in the vicinity of the metropolitan regions of San Salvador de Jujuy, Salta, and San Miguel de Tucumán, which together total almost 2 million inhabitants and host important infrastructure.

In order to improve the neotectonic characterization of potential seismogenic sources in this region we have employed a multidisciplinary and multimethodological research approach that includes remote sensing analysis, detailed structural and geomorphic mapping and topographic surveying, interpretation of seismic reflection lines and near-surface geophysical surveys, structural modeling, the deployment of temporary local seismic networks, as well as geochronology. The geochronological methods include terrestrial cosmogenic nuclide (TCN) dating and U-Pb dating of volcanic ashes to establish the age of abandoned fluvial terraces (10^4 to 10^5 yrs), and optically stimulated luminescence and AMS^{14}C dating to constrain the depositional ages of sedimentary sequences on centennial to multi-millennial timescales.

In this context, the Medeiros anticline has been already characterized as an N-S oriented, 16 km-long, fault-propagation fold deforming the entire sedimentary cover through a blind 30°W dipping ramp and a sub-horizontal detachment located in the contact with the metamorphic basement. Syntectonic unconformities in the synorogenic deposits allowed to establish the onset of the fold growth by upper Pliocene times. The Medeiros anticline is the southern termination of the La Caldera-Vaqueros ranges, representing as a whole a more than 60 km-long structural block.

Recently obtained TCN ages from two (T3 and T5) of the six (T1-T6 from oldest to youngest) folded fluvial strata terraces of the Vaqueros River, which cross the Medeiros anticline in an E-W direction, allow us to calculate average slip rates of 2.8 mm/a for the last ca. 45 ky implying a much higher potential seismic risk for the capital of Salta province that has rapidly expanded over the Medeiros anticline in the previous decades.

Seismotectonic and paleo-seismology insights of the Fortuna Fault and the Venado Transtensive System, Costa Rica.

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Costa Rica's northern back-arc region is crossed by a dextral strike-slip system called the Haciendas-Chiripa-Fortuna fault system (HCFS). The Fortuna Fault is a northwest dextral strike-slip structure that causes the Venado Transtensive System (VTS) due to a right bend along the fault. The Fortuna Fault marks a limit of the Guanacaste Volcanic Sliver, that is moving NW about 11mm/year. The study area is near Arenal volcano, which maintained a decades-long eruption between 1968-2010, and close to two important active-fault systems. The Venado region is located within a back-arc Miocene Sedimentary basin with Limestones and karstic elements covered by Plio-Quaternary volcano units. The zone has a predominant transtensive stress with a dominant morphological-structural control on NNW-SSE and a smaller one on E-W direction. This zone shows active tectonics evidence and karstic elements such as deflected drainages, linear valleys, shutter ridges, sag ponds, and a relevant variety of recent structural information on the caves and karst. The shallow seismicity is low and varies between Mw 1.5 - 4.5. Using drone photogrammetry, karstic and cave geology, geological mapping, structural geology, seismotectonics, and geomorphology, this work contributes to the Fortuna fault characterization and provides a better definition of the HCFS to improve the seismic hazard assessment, risk management and contribute to the characterization of the tectonic sliver of northern Costa Rica.

Palaeoseismic record in Pyrenean lakes.

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Lacustrine sediments are useful as a source of paleoseismic information, mainly due to their ability to record the shaking produced by an earthquake and their great temporal resolution in cases of continuous sedimentation. The Pyrenees are one of the main active seismic zones in the Iberian Peninsula and understanding the behavior of their seismogenetic structures is extremely important to generate adequate seismic risk models. The low recurrence of moderate to large seismic events makes it difficult to have a robust historical and instrumental record and, therefore, paleoseismology is an optimal tool for studying the seismicity of the area. Contrasting with the scarcity of palaeoseismic studies on active faults in the Pyrenees, there is considerable information on the sedimentation recorded in Pyrenean lakes. Thus, in this study, the existing lacustrine records of the Pyrenean lakes are used to identify deformation structures resulting from seismic events and correlate them with historical seismic events such as the Ribagorza earthquake of 1373, whose seismogenetic source is presumably the North Maladeta Fault system.

In the records obtained from lakes near the North Maladeta Fault system, such as Cregüeña, Barrancs and Estaña, the presence of seismic-type deformation structures of various dimensions has been evidenced that may be related to the 1373 Ribagorza earthquake, since that match the age pattern of the lakes. The Ribagorza earthquake is the most relevant historical seismic event that has occurred in the Central Pyrenees. Previous studies detail the connotation that the earthquake had on the inhabitants of Catalonia in the Middle Ages. This event had an estimated magnitude around Mw 6.2 and a maximum intensity of VIII-IX in the epicentral zone.

Morphotectonics of the “Depressão Periférica Paulista” and basaltic cuestas, at the areas of São Carlos, Rio Claro, São Pedro and Piracicaba (São Paulo-Brazil)

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Neotectonic structures were investigated within the “Depressão Periférica Paulista” and basaltic cuestas, two major geomorphological units in the areas of São Carlos, Rio Claro, São Pedro and Piracicaba (São Paulo, Brazil). The research was based on geological and geomorphological data, with emphasis on drainage pattern and anomalies, lineaments and digital terrain modeling, in order to define the overall morphostructural and morphotectonic characteristics of the region. The main structural features identified are two faults systems. The older one is represented by normal faults, oriented preferentially NE-SW, that mark the oldest limits of the Cenozoic infill. They represent an extensional stress regime with $\sigma 1$ vertical, $\sigma 2$ NE-SW and $\sigma 3$ NW-SE. The younger group is characterized by strike-slip faults oriented preferentially E-W. The stress field is marked by $\sigma 2$ vertical, σ 1 NW-SE and $\sigma 3$ NE-SW. Other faults, oriented NE-SW and N-S, are also associated with a strike-slip regime. In this region, upper Cenozoic deposits are characterized by a basal conglomerate and an upper sandy-clayish unit, the later also intercalated with debris flow deposits. The Cenozoic is distributed in a discontinuously pattern, expressed by structural and lithologic steps, controlled by the main lineaments NW-SE, NE-SW, E-W and N-S. These lineaments impose tectonics landforms by tilting, which created escarpments, with triangular or trapezoidal facets, abandoned meanders, river captures, shutter ridges, offsets, lateral migrations, arches and elbows. These features are related to the neotectonic activity, due to rotation of the South American Plate, interpreted as dextral.

Active faults of the Andean Active Orogenic front (32° 30´S)

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The Andean active orogenic front, located in the Precordillera foothill at 32º 50'S, gathers the largest Quaternary deformation of Argentina. This region is related to intra-plate seismicity linked to the Pampean Flat Slab segment, the subduction of Juan Fernandez Ridge, a volcanism absence, and the particular morphostructural style of the morphotectonic unit of Precordillera (Southern Precordillera) that culminates at this latitude (32°S). Besides, a change in the style deformation of Quaternary structures is determined at this latitude, where folds limited by active faults and N-S reverse faults offsetting Late Pleistocene alluvial levels, predominate. In this study, the main Quaternary faults were studied. The maximum probable earthquake magnitude associated with these structures was established (~Ms=6.4) based on parameters measured along fault planes. The result was compared with values obtained indirectly by fault long. According to morphometric indices, the greatest current deformation area was located in the southern portion of the Andean piedmont. This zone shows as well the greater deformation detected by interferometry (DINSAR technique). Optically Stimulated Luminescence datings on sag ponds related to active faults allow to infer a regional slip rate during the Late Pleistocene.

Session 185: Active faults evolution: revelations from different timescales

Temporal variations in deformation rates from structural modeling, Quaternary dating, and geodetic measurements: Zagros Mountain Front Fault, Kurdistan Region of Iraq

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Constraining a responsible temporal record of active faults is usually associated with considerable complications. However, this record may provide hints toward the predicted trend of its activities. Here, we evaluate the temporal variations in the deformation rates on the Zagros Mountain Front Fault since its initiation in the Late Miocene. The Mountain Front Fault makes a prominent morpho-tectonic boundary along-strike of the entire Zagros Belt, and it is seismically active (e. g. 2017 Mw 7.3 earthquake in the Iraq-Iran border). The long-term (geological) deformation rates were measured from balanced cross-sections and structural forward modeling. The Late Pleistocene-Holocene slip rates were calculated from fault-related fold modeling and differential uplift rates of associated river terraces on both hanging wall and footwall. The results were then compared to the present-day geodetically derived deformation rates in that region. The total displacement on the fault since its formation in the Late Miocene, derived from the balanced cross-sections, was used to calculate slip rates of about one millimeter per year. In contrast, the Late Pleistocene-Holocene calculated slip rates are 1.9±0.7 millimeter per year. Interestingly, the geodetically-derived deformation rates for that area are much (3-5 times) higher than both previous rates. This study shows that combining multiple approaches allows for better constraints on the temporal behavior of active faults. Discrepancies in estimates obtained via these three approaches might thus allow to identify locked fault strands that pose an increased seismic hazard.

New multidisciplinary investigations on the tectonic and sedimentary evolution of the southern sector of Sulmona basin (Central Italy).

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The Sulmona intermontane plain is a tectonic basin filled by Quaternary fluvio-lacustrine deposits, driven by the recent activity of the Mt. Morrone fault system during the post-orogenic extension of the Central Apennines. Detailed multidisciplinary investigations were carried out in the southern sector of the basin, in the Santa Rufina (SR) borehole. SR was drilled down to a depth of ca. 200 m in the western section of the basin and compared with a ca. 435-m-depth water-well (Medibev Well: MW) in the depocentral portion of the basin, characterized by a lacustrine succession.

Although recent studies have explored in detail the stratigraphy of the Sulmona Basin, these are generally limited to the northern sector of the basin, leaving open numerous issues, such as: the overall geometry and stratigraphy of the basin infill, the depth of bedrock/sediment interface, the onset age of the basin formation, and the relations between the basin subsidence rate vs. Mt Morrone fault slip-rate. In both SR and MW sediment cores the lacustrine clayey-silty deposits dominated with respect the coarse grained alluvial-fluvial deposits.

The magnetic susceptibility of SR, measured both on the core and on discrete samples, shows higher values corresponding to tephra layers. The paleomagnetic analysis, performed by alternating field demagnetization on 156 samples, identifies the Brunhes/Matuyama boundary (773 ka) at 194 m depth.

Tephrochonological analysis in SR core allowed the recognition of several chronologically well-constrained tephra markers, either of regional (e.g., Vico a, ca. 415 ka, White Trachitic Tuff, ca. 320 ka, and Villa Senni, ca. 366 ka) or basinal scale, which constrain the whole succession between ca. 300 and 800 ka.

The comparison of the coarse grained alluvial and tephra layers in the two boreholes constrained a geological section crossing the basin, which allowed new insights into its tectonic, sedimentary and paleoenvironmental evolution. Preliminary results from the correlation confirmed an asymmetric half-graben type geometry of the basin, highlighting the Mt. Morrone fault system as a leading factor responsible for the opening of the basin and its Quaternary tectonic-sedimentary evolution.

Long-term evolution of the Mt Pettino seismogenic fault zone (central Apennines): structural, isotopic, and geochronological constraints

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The central Apennines are a Cenozoic fold-and-thrust belt that is undergoing post-orogenic collapse in its axial region since the Pliocene. Post-orogenic extension resulted in the formation of several intermontane basins bordered by high-angle extensional faults, striking subparallel to the backbone of the chain. The Monte Pettino seismogenic fault (MPF) is the NE boundary fault of the Quaternary L'Aquila intermontane basin. Its fault zone is characterized by a complex structural architecture that documents a polyphase tectonic history. To study the long-term evolution of the MPF, we integrated fieldwork, geochemical (C-O stable isotopes), and geochronological (U-Th) analyses. Our study highlights two main tectonic phases. The first phase corresponds to the development of a major cataclastic zone, defined by an 8-meter-thick SW-dipping (65-70°) fault core exposed at the piedmont of the Monte Pettino. This cataclastic zone is sealed by the L'Aquila Breccias (Middle Pleistocene, ca. 250-350 ka). The stable isotope systematics of the cataclastic matrix and of the associated calcite slickenfibers, which are in the range of the carbonate bedrock, indicates a "closed" system behaviour during fault zone nucleation and development. The second phase, is recorded both in the L'Aquila Breccias and in discontinuous volcanic deposits, interpreted as pyroclastic products of the Albani Hills, which unconformably cover the bedrock at the SE termination of the MPF. It consists of anastomosed, high-angle WNW-ESE striking fault strands, spaced m to hm apart and with cm to m displacements, associated with carbonate veining and travertine formation. Stable isotopes measured from the fault slickenfibers show a progressive re-equilibration with meteoric fluids, as evidenced by a decreasing trend in $\delta^{13}C$ and $\delta^{18}O$ values. The carbonate veins and travertines systematically show negative $\delta^{13}C$ and $\delta^{18}O$ values, showing a dominant supply of meteoric fluid ("open" system) with important contribution of organic carbon. The U-Th ages of the veins and travertines are in the range of 182-331 ka, in accordance with the temporal constraints from stratigraphic data. Structural and isotopic results have supplied no evidence of tectonic reactivation of the cataclastic core of the MPF during the Middle-Upper Pleistocene, suggesting that it was already exhumed at that time.

Quaternary activity of the Viar and Medina Azahara faults in a strongly strain partitioned, tectonic scenario: new constraints from geomorphic analysis and 10Be-derived denudation rates

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Relief rejuvenation of geologically ancient areas often occurs in response to intraplate deformation. In these long-lived areas, the reactivation of pre-existing structures is a common mechanism for strain accommodation, which is often favored over the generation of new structures. Thus, previous discontinuities can be expected to localize the relief rejuvenation associated with recent or active tectonics, which can therefore be analyzed to delve into the kinematics of recent deformation.

In this regard, we explored the relationship between the relief rejuvenation pattern and the distribution, geometry, and kinematics of Viar and Medina Azahara faults in a wide segment of the Betic foreland (Sierra Morena, southern Spain). Specifically, we focused on the forebulge, a WSW–ENE flexural relief that formed, paired to the Betic foreland basin, in response to orogenic load, where little work has been done to address the geomorphological imprint of the tectonic rejuvenation in the Sierra Morena.

For this purpose, we applied both qualitative and quantitative geomorphological tools, including geomorphic indices and knickpoint pattern modeling in order to detect transient signals along the river profiles linked to the fault activities. Moreover, to investigate how the denudation rates vary in relation with the fault activity, we measured the content of in situ-produced cosmogenic ^{10}Be of river-borne quartz from sands samples collected in active channels of 8 sub-catchments of Viar basin upstream to the Viar fault and 7 sub-catchments of Guadiato basin upstream to the Medina Azahara fault.

We found that the sampled sub-catchments are in disequilibrium conditions with non-lithological knickpoints delimiting a relict landscape with lower denudation rates from rejuvenated and active landscape with higher rates.

Multi-scale definition of the activity rates of segmented faults: the case of the Mt. Marine Fault (Central Apennines, Italy)

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The understanding of the dynamics of highly segmented faults is made difficult by the lack of information on whether the 3D shallow deformation is equally spread over multiple fault splays or the activity tends to localise on specific splays. This problem is enhanced when these faults are located within urban areas, and therefore their surface expression is altered by intense anthropic activity.

Within the framework of a work on the mitigation of the fault displacement hazard associated with the Mt. Marine active normal fault (Central Italy), we have performed two paleoseismological surveys within the town of Pizzoli (about 10 km NW of L'Aquila), where the fault is expressed with several splays arranged both along and across-strike. The trenches were planned in order to explore (i) potential fault scarps altered by human activity, identified through aerial photographs, LiDAR and fieldwork analysis, and (ii) discontinuities in the stratigraphic record highlighted by geophysical investigations (ERT, GPR) and borehole data. The first survey is characterised by a continuous trench about 156 m long and it intercepts two synthetic and one antithetic faults arranged across-strike. The three faults show evidence of multiple Holocene surface-rupturing seismic events, marked by colluvial wedges and infilled fractures, with observable coseismic displacement up to 80 cm. The second paleoseismological survey is located about 720 m SE of the previous site, and it is composed by two adjacent smaller trenches, with length about 20 m and 10 m each. These trenches intercept two faults arranged across-strike, both providing evidence of repeated Holocene surface-rupturing earthquakes.

Moreover, we constrained the Late Pleistocene slip-rate of the Mt. Marine fault by dating and correlating Late Pleistocene paleosols found (1) outcropping in the footwall of one of the inner fault splays and (2) in a borehole located just at the hangingwall of the outermost splay.

Our results show that multiple fault splays are active with different rates through time, suggesting that the activity is localised on specific splays. The comparison between the Late Pleistocene slip-rate and the paleo-seismological results allows us to understand how single fault splays contribute to the overall behaviour of segmented active faults.

Active tectonics of the Cordillera de la Sal fold-and-thrust belt, Salar de Atacama, Chile. Evidences from deformed fluvial features

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The Salar de Atacama basin is a low topographic anomaly located in the proximal forearc of the Central Andes (~23°S, Chile). Within the Salar de Atacama depression, we focus on the Cordillera de la Sal (CdS), a ridge that emerges on its western margin and extends to the northeast for more than 100 km towards the volcanic arc, where the Salar de Atacama basin closes. The core of the CdS ridge is formed by a fold-and-thrust belt affecting the Oligocene-Miocene continental sedimentary successions of the San Pedro Formation. Towards the volcanic arc, these units are unconformably overlain by Upper Miocene-Pleistocene tuffs and sediments with varying intensities of deformation. At this latitude, the Andean active crustal tectonics is characterised by extension in the external part of the forearc, whereas by compression in the retroarc. Nevertheless, there is discussion about the recent Pliocene to Late Pleistocene tectonics affecting the Salar de Atacama area.

Our objective is to contribute to the understanding of the Neogene to recent tectonics of the proximal forearc of the Central Andes by constraining the variable spatial patterns of deformation affecting the CdS. Our methods combine a detailed geological mapping of the northern segment of CdS and the construction of cross-sections with geochronology and structural modelling.

In this work, we provide field evidences of Late Pleistocene to Holocene active tectonics, which is deforming fluvial features that cross the frontal structures of the CdS, such as deformed fluvial strath terraces and Holocene salt cave conduits. Moreover, we present novel geochronological data for the deformed strath terraces, which we are currently dating using Infra-Red Stimulated Luminescence methods. This new geochronological data will allow us to constrain the variability of the incision rates associated with the streams that cut the deformation front of the Cordillera de la Sal and to model the slip rates of the thrust structures at different time scales.

Evidence of Late Cenozoic reactivation of an inherited strike-slip fault system in the Longitudinal Valley of Northernmost Chile

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The Longitudinal Valley in Northernmost Chile is the main depocenter of widespread fluvial-alluvial systems active through the Neogene until exoreic drainages developed between Arica and Pisagua ca. 3 Ma ago. The top surfaces of the continental deposits form a regional scale pediplain (Pacific Paleosurface), where present-day perennial streams drain to the Pacific Ocean trough deep incised quebradas. Some geomorphic and climatic constrains exists regarding how uplift of the Coastal Cordillera and western Andes influence the shift in drainage regimes. However, little is known how tectonic activity across this region affected landscape evolution since the structural architecture is difficult to unravel in this area of high sedimentation but low displacement rate.
To address this, we combined a reprocessed ENAP (Empresa Nacional del Petróleo) seismic section comprising the forearc at ~19°20'S with detailed structural mapping and geomorphic evidence in key areas to unveil deep to surface geometry, kinematics and timing of tectonic structures across the Longitudinal Valley. Our first observations led to strong evidence of the existence of a complex Mesozoic inherited strike-slip system across the Longitudinal Valley which reactivation deformed Oligocene to Late Miocene strata. Local growth strata, angular unconformities, and flower structures within Late Miocene to Early Pliocene lacustrine deposits suggest syn-sedimentary and later dextral transpressional faulting along the boundary in between the Longitudinal Valley and Coastal Cordillera during this period. Surface expression of these structures consist in gentle bulging with normal faulting across folds. Importantly, timing of faulting matches with the major draining event of the paleolake. Then, these structures localize later large landslides events inside the deep quebradas. Progressive abandonment and deformed terraces of low incised rivers crossing compressive structures suggest that these are active during the Quaternary. New dating of deformed marker horizons will bring further insights regarding key parameters of fault activity for the Late Cenozoic and Quaternary. One important result of this study is that we observe large drainage reorganization patterns triggered by only little displacement along the often blind fault structures, that create nevertheless enough topography that cannot be surpassed by drainage incision in this hyperarid setting.

Session 186: The Long Walk to the Anthropocene: Exploration within Quaternary contexts

Timing of the anthropogenic carbon invasion in the Southern California Current surface waters

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High resolution carbon isotopic records from organic and carbonate carbon show an unprecedented several decades long decreasing trend in their stable isotopic compositions for the past millennium. These time series were obtained from laminated cores collected from a semi-closed basin off Baja California Peninsula, San Lázaro basin (SLB), bathed by suboxic waters at depth, and located below the southern dynamic boundary of the California Current System. The carbon isotopic compositions of two planktic foraminifera *N. dutertrei* and *G. ruber* show a decreasing trend toward lighter isotopic compositions during the past 8 decades, further reflected in the organic carbon isotopic composition. These trends are similar to the widely observed trend toward lighter carbon isotopic values in the atmospheric CO_2 although with slightly lower slopes. These trends most likely result from the invasion of anthropogenic carbon dioxide in the surface waters of the California Current, another expression of the Suess effect in the upper ocean waters. Their different slopes are most likely due to the combined effects of vertical mixing of subsurface nutrient driven by the dominant NW winds along the western North American margin bringing nutrient and dissolved inorganic carbon rich waters characteristic for their relatively heavier carbon isotopic values, and the equatorial advection of northern waters carrying anthropogenic carbon dioxide in this highly productive eastern boundary current.

Lead legacy of preindustrial activities in lake sediments: the case study of the Lake Accesa (Southern Tuscany)

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Geochemical analyses of long-time series provided by lacustrine sediments can give new insights into the possible contribution of preindustrial activities to the trace metal dispersion in the environment at different scales (e.g., local and regional scales), and into the natural background conditions of selected areas. The Mediterranean basin, and especially Italy, has a long history of civilization and anthropic modifications and hosts some of the largest metal mines in the world, therefore is perfectly suitable for a wider study on this matter.

For this project, we selected five different lacustrine cores from lakes mainly located in Italy (Lake Ledro, Lake Accesa, Lake Lungo, Ganzirri salt-marsh and Lake Volvi) and dating back to the second half of the Holocene to trace local-to-regional Pb pollution for a preliminary resolution of ca. 200-300 yr.

Data for lead indicates that most lakes recorded an increase in lead concentrations moving toward the uppermost part of the cores. However, among the lakes, the Lake Accesa is the only one that shows incredibly high concentrations of lead, with values up to ~1600 ppm starting from the Middle Age. The Lake Accesa is a small karstic lake (~0.15 km²) located on the southern border of the Colline Metallifere mining district, which is characterized by widespread hydrothermal mineralization. The catchment area of the lake (about 5 km²) is also surrounded by sulfide polymetallic deposits exploited in the last centuries. The high values detected in the Lake Accesa could be thus related to the growth of human activities during the Middle Age that favored soil and sediment erosion of different areas of the catchment such as mining and agricultural activities. This means, for example, that preindustrial activities in southern Tuscany may have left an important legacy of potential toxic elements in the environment, even higher of the recent pollution.

The politics of plants: socio-political contexts as drivers of upland cultural land-use change, impacts on landscape and ecosystem. The Cabreira Mountain, northwest Portugal.

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In many regions today, mountain landscapes are under threat from climate change, degrading ecosystems and rural exodus, despite a long history of human settlement and exploitation. The present study aims to reconstruct human activity in the Cabreira Mountain, in northwestern Portugal, to investigate the degree to which human interaction with the mountain environment has contributed to shifting landscapes and ecosystem demise throughout the last millennium. This study offers a long-term perspective on the evolution of cultural land-use in the context of ongoing social and economic change through the examination of three palaeoenvironmental sequences interpreted in the light of available archaeological, historical and documentary records. Social-political factors and population pressure were fundamental in the utilisation of upland spaces and in defining the economic structure of the uplands.

We conclude that long-term occupation of the uplands was sustained by low-intensity land-use throughout the Medieval to post-Medieval periods, and that the present landscape has assumed a very different character following depopulation of the mountain areas and a shift towards commercial forestry. The analysed palynological sequences have addressed gaps in the archaeological and historical evidence, such as the nature of land-use in the uplands of northern Portugal, the impact political crises had on upland economy and the role of mountain regions within the wider economic setting. This study has also highlighted the importance of traditional management systems in maintaining landscapes and healthy ecosystems: the demise of the traditional land-management practices led to landscape degradation, increased fire vulnerability, changes to the water cycle and increasing aridity.

Back to the Grind: A Study of Grinding Stones in the Southern Indian Neolithic

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This paper discusses grinding stones from the Indian Neolithic seeking to examine issues related to subsistence, social organisation and degrees of sedentism. The study moves beyond typological lists of grinding stones, commonly noted in Indian archaeological literature, towards an interpretation of their reduction sequences, use, reuse and discard. This research focuses on the southern Indian Neolithic complex (c. 2500-1400 BCE) particularly reviewing the context and nature of grinding stones present at the site with issues related to subsistence, mobility and intra- and inter-site spatial organisation. In this study, we analysed a total of 109 grinding stones from the sites of Sangankallu, Budihal and Tekkalakota. These sites have a long history of research with evidence of the transition from hunting-gathering to agro-pastoralism, the evolution of the Neolithic and transitions to the subsequent 'Iron Age', marked by cultural changes reflecting adaptation to differing ecological 'niches.' In addition to metrical and qualitative variables, 3D Photogrammetry was attempted to further interpret variability in surfaces utilised. We evaluated the context where each grinding stone was found alongside its morphology and potential strategies for manufacture, use and discard, in order to reconstruct its life history. Results indicate some degree of commonality amongst different types of grinding stones found at these sites, with the presence of both portable and non-portable grinding stones. The artefacts reflect complex life histories culminating in breakage, rejuvenation, reuse and discard. Our research suggests that grinding stones, which are essential elements of food processing in agro-pastoral communities both in the past and today, are important indicators for activities such as plant processing and non-subsistence-related activities. They can help us better understand important issues such as seasonality and degrees of sedentism amongst Neolithic communities in southern India. Grinding stones form a key element in multiple aspects of the lives of agricultural communities in India, not only in the past but also in the traditional lifeways of modern India. The significance of this study lies in analysing these artefacts from multiple perspectives and how they are instrumental in understanding changing human interactions with the 'wild' and 'domesticated' landscapes through time.

Pollen based reconstruction of vegetation dynamics in the urban fabric of an Ancient lost capital - Angkor Thom, Cambodia

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This paper presents the first results from a palynological study of cores recovered from an organically rich deposit at the bottom of the Srah Srei, a tank that was built on the grounds of the Royal Palace in Angkor Thom. The sediments date back to at least the mid 13th century. The vegetation in the vicinity of the tank was very different in the past from the one we find currently both in terms of the overall tree cover and in the possible assemblages making up this tree cover. We present the vegetation succession from the time of the initiation of the tank in these palace grounds to the abandonment of this urban space in the overall context of a new explanatory model of the Urban fabric of Angkor Thom developed by combining long term archeological studies with recent excavations and other interdisciplinary approaches to the archeological study of this site.

What and whom is the category of the 'Anthropocene' good for?

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The Anthropocene debates are rooted in epistemological differences. Geologists seek temporal markers of spatially-even anthropogenic impact. Thus, they favor geologic data that fit this category. Humanists and social scientists, on the other hand, tend to focus on the negative effects of spatial unevenness. Without linking the Anthropocene's temporal and spatial components, the official designation, ultimately determined by geologists, will be a futile exercise that will not make good on the Anthropocene Working Group's intention for it to be useful for wider segments of society. However, if the Anthropocene is divided into an Early, Middle, and Late Anthropocene, each defined by geologic evidence, the uneven spatial distributions of anthropogenic damage can be traced to specific events in human history, thus actualizing the predictive value of geology. Further, this diachronic scheme, unlike the synchronic ones thus far proposed, makes more legible two fundamental dynamics between human and natural trajectories: the intensification of global inequity coterminous with the intensification of natural damage; and humanity's ever more audacious attempts to control the environment. This ethos, wielded as the prime justification for taking over that which belonged to cultures not espousing it, has resulted in anthropogenic damage disproportionately affecting the most economically and historically vulnerable peoples. However, their alternative modes of coping with the damages—an ineluctable responsiveness to, rather than control over, environment—enables them to survive. As such, they could lead the way through the Anthropocene, modeling adaptation and mitigation strategies, and obviating the global North's unsound hope for a technological solution. By expanding the data beyond the stratigraphic, coordinated interdisciplinary research can measure variegated effects of—-and responses to—-the Anthropocene, thus better equipping humanity to adapt to and/or mitigate climate change and to eschew unsustainable practices.

Session 187: Equity, Diversity and Inclusion Initiatives in the Quaternary Sciences

Enabling equitable cultures of knowledge and practice in physical geography and environmental sciences.

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Studying geography and / or environmental science are two of the pathways into the Quaternary Sciences. There is significant under representation within these disciplines with respect to gender, race, class, sexual and gender identity, disability, those with caring responsibilities, social class, and their intersectionalities. The subjects are rooted in colonial cultures of scientific knowledge production and practices, and the relationship between decolonising knowledge production and equality, diversity and inclusion (EDI) challenges is entangled.
Our 'Enabling equitable cultures' project aimed to find out about the EDI challenges UK-based physical geographers and environmental scientists faced through different stages of their career. We focussed on finding out about:

- The lived experience of individuals and allies
- The EDI needs and gaps across institutions
- The positive work in the community (to develop and share good practice)

We worked with an advisory group of geographers from 10 UK higher education institutions to map current EDI work, with EDI consultants, and held focus groups with individuals from 23 institutions in the UK. The areas for discussion in the focus groups arose from a review of the current literature and data, and conversations with the advisory group. The focus groups:

- Examined the experiences of specific groups of staff and students within Geography departments (undergraduates, postgraduate researchers and postdocs, and technicians)
- Explored areas we knew that positive EDI work was happening (decolonising the curriculum, and accessible fieldwork)
- Discussed emerging and overlooked issues (support around neurodiversity, trans and non-binary, and socio-economic class).

Together with a specialist EDI consultant we developed an 'Enabling Equitable Outcomes' maturity matrix for our community to use, alongside a set of online resources, to support departments to reflect on progress and take actions that contribute to greater diversity within the discipline, help to deepen the community's commitment to systemic change, and which will help to build communities of practice around EDI work in Geography and Environmental Sciences.

Communicating geoarchaeology and paleopedology: Experiences with the young Latino community

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1. *National Autonomous University of Mexico,* ***2.*** *Instituto de Geología, Universidad Nacional Autónoma de México, Mexico City*

The soils serve several functions in the ecosystems and have played as scenarios for human development. Right on, soil scientists and archaeologists have noticed this fact and started interdisciplinary approaches through geoarchaeology and paleopedology. Nevertheless, it implies a certain degree of academic specialization which complicates its dissemination to a wider people. In this way, the Institute of Geology (National Autonomous University of Mexico, UNAM) and Proyecto Suelox have developed infographics, workshops, and podcasts to communicate this knowledge with the Spanish-speaking community. The *Edafografías* project (infographics on soil science) was launched in 2020 as an element of marketing for the Proyecto Suelox educational projects on social media (@psuelox). For 2021, there was a season dedicated to the *Ibero-American Workshop on Paleopedology and Geoarchaeology*. While the online workshop offered lectures on *Soil memory*, *Applied Micromorphology and Micromorphometry, Pre-Quaternary and Pleistocene Paleosols, or Dating techniques in Geoarchaeology*, the infographics were focused on more specific and complementary topics like *Karstic environments, Paleo-fires, or Erosion in archaeological sites*. Both the infographics and workshop impacted 17 countries in the Americas and Europe including non-Spanish-speaking countries such as Brazil, France, and Serbia. Particularly, the main participants of the workshop were young bachelor's students. On the other hand, *Suelófono: the very first podcast on soils in Spanish* is a project supported by the International Union of Soil Sciences with short interviews with senior soil scientists. So far, two seasons have been launched, being episodes like "What is soil?" with Sergey Sedov and "The ancient soils" with Elizabeth Solleiro two of the most listened episodes in more than 20 countries including non-Spanish-speaking regions in Central Europe and the Middle East. We have detected a Hispanic community interested in geoarchaeology and paleopedology in Latin America and beyond, between 23 and 34 years old, with equity conditions in masculine and feminine and minorities of non-defined and non-binary gender identities.

Decolonisation and the Geosciences: challenges and opportunities

Prof. Peter Langdon [1], ***Dr. Chris Prior*** [1], ***Dr. Joe Higgins*** [1], ***Prof. David Sear*** [2], ***Ms. Kimberley James*** [3], ***Ms. Fiona Oakley*** [3], ***Mr. Kiatapu Lopati*** [4], ***Mr. Roger Malcolm*** [5]

1. *University of Southampton,* ***2.*** *School of Geography and Environmental Science, University of Southampton,* ***3.*** *Gilbert Whites Museum,* ***4.*** *Nanumea Island Council,* ***5.*** *The Island Council, Atiu*

Decolonisation is often a difficult term, but one we need to confront within Quaternary Science (and the wider Geosciences), if we want to develop our science to be fully inclusive, and to recognise that indigenous people have agency. At its simplest, decolonisation could be described as looking at things from different perspectives, and then working outwards. In terms of Quaternary science, this could relate to working with indigenous people and involving them in the research, especially as many communities may have oral traditions and/or histories which will likely provide an alternative viewpoint. Many of us may work on sites that are sacred to the local communities, and we should consider carefully how we could incorporate those communities into the research, from first principles to undertaking and reporting the work.

Here we draw on work from two very different projects. The first is work with colleagues from history, focused on trying to uncover the hidden histories within historical texts – to consider how we can read against the grain, and how these alternative views may inform us more broadly. The context is around 'the scramble for Africa' in the mid to late 19th

century, and we will consider how we can apply our learning to elements of Quaternary science, notably around biodiversity and conservation. The second project is focused on reconstructing past climate change from remote Pacific islands using lake or swamp archives. In these islands we have been working with indigenous communities to consider ways to co-produce the research effectively for all concerned. In one low lying Atoll threatened by rising sea levels and droughts, we are remotely supporting local people to undertake the lake coring work to reduce the emissions we make during traditional field work visits. In the second we illustrate how engaging with local communities enriches both the interpretation of the data, but also raises the awareness of the heritage and cultural value of their lake sediment archives.

Broadening Brown v. Board of Education's Impact: Toward Inclusive Pedagogies in Archaeological Research

Dr. Laura Murphy [1]

1. Washburn University

In June 2022, as part of a five-week field school, Washburn University students conducted archaeological field and laboratory work at Brown v. Board of Education National Historical Park in Topeka, Kansas, USA, in collaboration with the Kansas Historical Society and Kansas Anthropological Association. The National Park includes the Monroe Elementary School building - a once segregated African American school attended by Linda Brown who was denied enrollment in the all-white but nearby Sumner School because of her race. In 1951, Linda's father, Oliver Brown, filed a lawsuit against the Topeka Board of Education to end segregation in public schools. On May 17, 1954, the US Supreme Court unanimously declared that "separate educational facilities are inherently unequal." Because of the importance of the Monroe School in the national story about the Civil Rights movement and Black history, excavations sought to answer research questions about the neighborhood prior to the construction of the school and during the school's operation. However, because archaeological research in the US is inherently colonial and predominately white, I sought new strategies to imbed diversity and inclusion into the field school course. As educators we must create anti-colonial and anti-racist curriculum in archaeology in order to break away from traditional work that excludes descendant communities and underrepresented students. Current archaeological pedagogy largely focuses on training students for jobs in cultural resources management or to prepare them for research in graduate school. I will discuss inclusive pedagogies and changes that I made to my field school course design, which included multi-vocal assigned readings, written reflections and discussion prior to fieldwork, daily reflections during fieldwork, and a final project that could be tailored to the needs and interests of each student from their own diverse backgrounds. One learning objective was to have students connect their field findings to both the longer history of the site and to modern concerns in our local Black communities. I will share examples of student work and their feedback on these initiatives. I will also provide strategies for continued community engagement and the importance of BIPOC and Queer voices in archaeological fieldwork and interpretation.

Session 190: Paleosol memory of environmental change and man-landscape interactions: from soil profile to geosystem

The enigmatic fills of Palenque constructions: how they can help to decipher the development of the city

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Palenque, an ancient Maya city (250-900 CE), was constructed on a karstic landscape, derived from folded limestones and sandstones. Some scholars have argued that only the civic-ceremonial core of the city was carefully designed, while the residential areas were lacking planning. We did a geoarchaeological survey to evaluate the differences among the construction materials used during the several phases of the development of the city. We worked in a building of the Group IV and accomplished the work with an off-site sampling. In the building, we recognized several infills corresponding to different construction stages, which are associated to burials. Soils around the city are yellowish sandy, derived from the Cretaceous sandstones. This soil cover has been also found under the building. The common elements observed in the infillings are: high amounts of silt, clay, and organic carbon, ceramic fragments, bones, charcoal, mollusks, and limestone fragments. One remarkable finding was the presence of travertine, extracted from the nearby river. Although these elements were present in all infills, they were in different amounts. Additionally, we observed that infills close to the burials showed pH values higher than 9 and only one (corresponding to the last construction stage) showed a positive reaction to HCl. We considered that these differences and similarities are related to changes in the political and economic conditions which could influence the availability of the construction's materials.

Changes of the environmental conditions of primitive societies in the center of the East European Plain over the last 20 thousand years

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On the right bank of the Middle Don, near the villages of Kostenki and Borshchevo, there is the largest complex of Upper Paleolithic monuments in Eastern Europe. Active geoarchaeological work aimed at reconstructing the habitat of ancient man has been carried out since the middle of the 20th century. Despite of the large number of paleosol studies of the Kostenki sites, the question of the genesis and evolution of paleosols and the conditions of their formation has not yet been resolved. Soil-sedimentary sequences containing cultural layers are not characterized analytically in sufficient detail, and a wider range of lithological-soil methods should be used.

The purpose of this study is to reconstruct the local natural environment on the territory of the Kostenki-17 archaeological site, from the late Pleistocene to the present. For the first time, for the sediment sequence at the Kostenki-17 site, lithological and soil analyzes were performed with high detailing: samples were taken from the wall of the excavation (with a total depth of 6 m) with a step of 5 cm without interruptions. The following types of analyzes were performed in sampled sediments: elemental composition, C:N ratio, magnetic susceptibility, spectrophotometric characteristics in CIE-L*a*b* system, particle size distribution, radiocarbon dating and hierarchical morphological description. Conducted analysis made it possible to divide the sequence according to the mechanisms of sedimentation, to reveal the participation of slope cryogenic, fluvial, soil biogenic and eolian processes. It was found that in the period earlier ~40 ka formation of sediments mainly occurred due to the filling of small channels of temporary water courses, which formed an alluvial fan. In the period from ~40 to ~20 ka processes of soil formation and solifluction alternated. Starting from ~20 ka the intensity of slope processes decreased, sedimentation occurred to a large extent, due to the eolian dust input. In the Holocene, the surface stabilized, and a full Chernozem profile was formed.

Mineralogical and geochemical records of environmental change in the Takatokwane Saline Pan, Southern Botswana.

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Soil-sedimentary sequences were exposed through local clay mining at the Takatokwane saline pan in the Kalahari Basin, southern Botswana. A combination of pedological, geochemical and mineralogical approaches were applied to study the pedosediments with the objective of providing insights into regional environmental change. Standard pedological parameters, such as structure, colour, bulk density, porosity, pH, electrical conductivity, organic matter content, carbonate contents and magnetic properties were determined using routine laboratory procedures. The total elemental composition and clay mineralogy analysis were done using the x-ray fluorescence spectroscopy and x-ray diffractometry respectively. Chemical index of alteration (CIA), chemical index of weathering (CIW) and index of compositional variability (ICV) were used to assess chemical weathering intensities. Molecular pedogenic ratios were used to quantify pedogenesis in the soils. An interplay of both pedological and geological processes shaped the pedostratigraphy of the Pan. The soil colour spanned grey to greenish. Electrical conductivity ranged from 1.92 and 6.45 dS/m. The soil pH ranged from 7.0 to 9.6 with high CEC (< 20 Cmol kg^{-1}). Elemental abundance followed SiO_2

$> Al_2O_3 > Fe_2O_3 > TiO_2$

pattern in two profiles. The clay mineral assemblages are smectite, sepiolite, vermiculite, kaolinite, montmorillonite and illite. Ground water had strong influence on pedogenesis. The degree of weathering of the soils are generally incipient as they had ICV >1 and CIA values < 60. The dominant pedogenic processes in the soils include hydrolysis, lessivage, leaching, eluviation, illuviation and gleization. Given the scares and discontinuous nature of archives for paleoenvironmental reconstruction in the region, finding of this study could be a valuable addition.

Understanding past environmental change in pedo-sedimentary sequences of coastal Sardinia (Italy)

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Along the Sardinian coast many sedimentary archives preserve the Quaternary history of this area of the Mediterranean. Sea level change dynamics during the last glacial cycles influenced the geomorphic processes, with a resulting variety of depositional environments and distinct phases of stability and soil formation. We present the preliminary results of an integrated approach focused on descriptive stratigraphic and geoarchaeological investigations and landscape survey on the Southwestern coast of Sardinia. We describe pedo-sedimentary sequences related to stratal architectures that date back to the Late Pleistocene, in order to understand the effect of the main geomorphic processes and of human presence in the evolution of the landscape.

Pleistocene-to-Recent coastal sequences lie on bedrock outcrops of Variscan basement composed of volcaniclastics, metasediments and schists. Locally, these appear intensely weathered and form saprolites, over which Late Neogene sediments have been deposited. Across the region, the basement metamorphic rocks weather quickly into heavy minerals as well as smectites and mixed-layer clays that impart popcorn textures and other shrink-swell attributes to the sediments. Granitic clasts composed of quartz monzonite break down into gruus, and the feldspars slowly degrade into kaolinite. Variously weathered Quaternary deposits attest mainly fluvial and colluvial processes during periods of marine regression. The Quaternary strata include marine beach clastics and carbonate-cemented fossiliferous beachrock as well as terrestrial fluvial, colluvial and aeolian facies. These sequences display various amounts of salt weathering, oxidation, bioturbation and pedogenesis. Rubified debris flow sediments and colluvial deposits are also likely anthropogenic in origin. These sediments preserve included artifacts – modern trash with plastics as well as artifacts from deeper time frames, including pottery, building materials and metal objects.

Soils in this region of Sardinia were originally mapped as Andisols. Careful re-examination of sediments comprising the coastal sequences suggests this is an oversimplification. Work is ongoing to better characterize the variables that influence the styles and rates of erosion and pedogenesis at different locales.

A re-evaluation of the MIS 3 palaeosol record at the Brno-Bohunice site (Czech Republic)

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Several important loess sections containing marine isotope stage 3 palaeosols have been discovered in the area of the Czech Republic. Most of them were previously examined mainly from an archaeological point of view in relation to the Middle/Upper Palaeolithic transition, and their palaeopedological records were not studied in detail. The crucial Middle/Upper Palaeolithic transition site has been discovered in Brno-Bohunice. A newly exposed loess section (Brno-Bohunice 2018) and a preserved section from the last archaeological research (Brno-Bohunice 2002) provide an opportunity to revise the Brno-Bohunice palaeosol record. We present a comprehensive multiproxy evaluation of soil development over the period of 60–30 ka BP, based on a combination of soil micromorphology and physical and geochemical proxies. Our study has shown that palaeosol development in the Brno-Bohunice area is more complex than previously assumed. Studied sections include three individual palaeosols, more specifically Cambisol, Tundra gley and Regosol. Cambisol developed most likely in GI 11, the Tundra gley probably in GI 9 and/or GI 8 and the Regosol developed from GI 7 onwards. Palaeosol or palaeosols developed during GI 13 and GI 12 are missing. Microscopic and macroscopic evidence indicates that records were strongly influenced by frost processes. Palaeolithic artefacts from the transition between the Cambisol and Tundra gley were probably lifted by freezing-thawing processes from an earlier position It is likely that even in the first excavated contexts were not necessarily found in their original position.

Calcretes and paleosols on Cozumel Island, Mexico; paleoenvironments implications for the Quaternary

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The calcarenite deposits, red clayey paleosols, and calcrete layers in outcrops of the Island of Cozumel is a record of terrestrial paleoenvironments that provides complementary information to the records studied so far in this region of the Caribbean Sea. Two outcrops were studied, Catera Payo Quarry and Cantera Transversal, and two soil profiles, Aerolito and Chempite, overlie calcrete layers. Micromorphological, physicochemical and mineralogical analyzes of soils and calcretes were carried out. A stable isotope analysis of C and O in calcretes was also performed. The chronological framework was obtained through the correlation of dated calcretes and coral samples from the Yucatán Peninsula, with ages ranging from Marine Isotope Stage (MIS) 7 to MIS 1. The red paleosols exhibited abundant redoximorphic features. The mineralogy of clays in paleosols and modern soils is similar, with vermiculite and minerals from the kaolinite group. We interpret them as the result of moderate weathering under a seasonal tropical climate like present conditions. The level where we find the soils is crowned by a layer of calcrete, whose age probably corresponds to Marine Isotopes Stage (MIS) 6 (164 to 135 ka). This calcrete's stable carbon isotope composition has a mean δ^{13}C value of −10.40 ‰, suggesting the presence of a C3 vegetation cover. During MIS 5, poorly cemented calcarenites accumulated on the island related to sea level rise during this interglacial stage. In the previously mentioned sections, formed in MIS 5 and the transition to MIS 4, there is another laminar calcrete with root traces and an alveolar septal structure. Its δ^{13}C value oscillates between −9.40 ‰ and −10.27 ‰, also related to a C3 vegetation cover. In the period between MIS 4 and MIS 1, karst development and pedogenesis are observed on the island, evidenced by the formation of caves and reddish-brown soils.

Session 193: Indo-Asian Monsoon on decadal to centennial-millennial scale and their link to the Indo- Pacific past climate variability

Impact of Ganga-Brahmaputra-Meghna runoff to the tropical Indian Ocean mixed-layer during the past 42 ka: foraminiferal Mg/Ca and B/Ca ratios and biomarkers (TEX86) approach

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Past studies reconstructed the Indian summer monsoon strength using marine and lake sediments, speleothems, etc., mainly focusing either on the upwelling region of the Arabian Sea or Ganga-Brahmaputra-Meghna (GBM) discharge, proximal to the continental margin inundated by the vast seasonal sediment discharge. A few studies reconstructed the Bay of Bengal (BoB) surface hydrology using a single foraminiferal species limiting profiling of the entire mixed-layer. Here, we present seawater oxygen isotopes ($\delta^{18}O_{SW}$) by making paired $\delta^{18}O$ and Mg/Ca measurements in *Trilobatus sacculifer* from a Bay of Bengal core CJ23-02 for the past 42 ka. Concurrently measured Ba/Ca ratios in the same samples were used with the $\delta^{18}O_{SW}$ to assess the GBM runoff. Further, the organic biomarker GDGTs was determined to estimate the water column temperature from the same samples. Our data show a striking temperature difference (ΔT) between the organic and inorganic proxies in which an inverse relationship between the paleo-proxy temperatures from 42.07-33.89 ka and 32.37-20.38 ka was observed. It is hypothesized that the ΔT may have been caused by either seasonality or depth habitats of the temperature recorder reflecting a variation in temperature between the shallow mixed versus deep mixed-layer. The $\delta^{18}O_{SW}$ and Ba/Ca ratios suggest a decrease in the GBM runoff, which might be caused by the weakening of the ISM during late MIS3-MIS2. Two dry HS1 and YD and one wet B/A intervals suggest a weaker and stronger ISM, respectively. In contrast, the speleothem $\delta^{18}O_{SW}$ show an opposite trend during the deglacial period. The divergence in the $\delta^{18}O$ values between the Arabian Sea and the BoB suggests different monsoon dynamics or isotopic fractionation. The highest Ba/Ca ratios and lighter $\delta^{18}O_{sw}$ during the early Holocene indicate an increase in GBM outflow and an intensified ISM. Our data corroborate that the high Ba/Ca ratios in the eastern Arabian Sea during the early Holocene (at 8.75 ka) was an independent event that could be linked to the low salinity Bay of Bengal surface water. The declining trend in Ba/Ca ratios and $\delta^{18}O_{SW}$ suggest a reduction in the GBM runoff, consistent with the northern Indian speleothems' records, during the late Holocene.

A lake-based reconstruction of late Holocene hydroclimate variability in the Garhwal Himalaya, India and links to the Indus Valley Civilization

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High-resolution analysis of a 3.80 m sediment core recovered from Deoria Tal, a mid-elevation lake located at 2393 m a.s.l. in the Garhwal Himalaya, documents long-term and abrupt hydroclimate fluctuations in northern India during the mid- to late Holocene. Analysis of lake sediment elemental concentrations, determined using XRF, and sub-fossil chironomid remains, pollen and sediment geochemistry were used to distinguish anomalous hydroclimate conditions during the interval spanning the rise, expansion, and eventual decline of the Indus Valley Civilization (IVC). The IVC was a socially complex, agrarian, and highly urbanized society, with well-developed infrastructure, including extensive sanitation facilities and hydraulic irrigation systems, located in northern India and Pakistan. It has been hypothesized that the stepwise decline and spatial contraction of the IVC was triggered by a severe and extensive drought episode associated with the widely recognized 4.2 ka event. The multi-proxy record presented here identifies major hydroclimate anomalies in the Garhwal Himalaya at 4200 and 3100 cal year BP.

General associations established between specific elements (K, Ti, Rb, Sr, Th) and sediment source and elemental ratios (Mn/Ti, Fe/Mn) and redox conditions suggest that the elevated Fe/Mn, lower Mn/Ti, and increase in allogenic detrital input evident between 4350 and 4200 cal yr BP, together with the shift chironomid assemblages and sediment geochemistry, reflect increasing lake levels and a positive hydroclimate anomaly during this interval. At 4200 cal yr BP an abrupt change, marked by prominent fluctuations in Th, Rb, Ti, Zr, Fe/Mn, and Mn/Ti, is inferred to reflect the onset of lake drawdown and is consistent with the occurrence of a negative hydroclimate anomaly between 4200 and 4050 cal yr BP. An episode of late Holocene peak aridity at ~ 3150 cal yr BP coincides with the timing of the disappearance of Indus culture in northwest India. Notably, this record suggests that the onset of de-urbanization and the deterioration of the Indus civilization at ~ 4200 cal yr BP coincided with largest hydroclimate anomaly evidenced in the Garhwal Himalaya during the last five millennia.

East Asian Monsoon response to abrupt global change during the last glacial period: evidence from the sediments of Lake Suigetsu, Japan.

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The East Asian Monsoon (EAM) impacts almost half of the world's population, however it's trajectory for the future remains largely unknown in light of current rapid climate change. This poster presentation will outline project plans and preliminary data with an aim to investigate the underlying mechanisms and long-term contributors to EAM variability. The project focuses on the sediments of Lake Suigetsu, Japan, and the episodes of abrupt global change leading into the last glacial maximum. Building on previous and ongoing research (see Francke et al. and Tyler et al.), this study aims to analyse oxygen isotopes from both biogenic silica and siderite, as well as diatom microfossil species abundances, from Lake Suigetsu's precisely dated varved sediments to reconstruct climate and hydrological change from ~50,000 – 20,000 years before present. In particular, here we will focus on the period of time from ~43,400 – 48,200 years before present, i.e. equivalent to Dansgaard-Oeschger event 12, to explore in detail the interplay between proxies and how they reflect sub-centennial scale teleconnections between Japan and elsewhere around the world. The data will be interrogated in the context of regional climate reconstructions, as well as climate model simulations. By improving the understanding of long-term drivers of the EAM, this study will contribute to improved estimates of future change in the region.

Uncovering Holocene Indo-Pacific linkage changes: proxy and model comparison

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The Indo-Pacific is a complex region affected by the El Niño-Southern Oscillation (ENSO), the Asian monsoon, and the Basin (IOB) and Dipole (IOD) modes in the Indian Ocean. Changes in one of these phenomena affect the others. There is still little agreement between future climate projections on how their interaction change under increased anthropogenic CO_2 emissions. To better understand these Indo-Pacific interactions, we focus on the Holocene, which began a little over 10,000 years ago. This allows us to put into perspective on a long time scale the links between changes in variability and changes in the mean state induced by insolation and greenhouse gas forcing. We consider four Holocene transient simulations with state-of-the-art climate models and a collection of paleo-archives in the Indo-Pacific region (planktic foraminifera, corals, and bivalves). Models agree on the long-term variability trends, but differences occur when we focus on finer scales (local sites where paleo-archives are). We analyze how the different simulations compare with the paleoclimate reconstructions and the relative role of temperature and salinity in determining the changes in $\delta^{18}O$ recorded by the various climate archives. We also investigate possible climatic shifts in the Indo-Pacific during the Holocene period.

Reconstruction of density stratification over Bay of Bengal Between LGM and Late Holocene

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Changes in density stratification of the Bay of Bengal (BoB) can induce a shift in rainfall patterns over South Asia and affects the socio-economic status of nearly 50% of global population. The instrumental data covering only a few decades from BoB provides conflicting observations on rainfall pattern with varying density stratification at interannual time scales. The demand for understanding the process in the long-term geological record become crucial for better understanding the role of salinity change on the hydrological circulation. In this study, we present the past observation on density stratification of Central BoB (CBoB) during past 25 kiloyears using the combination of conventional high precision IRMS analysis with Laser Absorption Spectroscopy. We apply the newly developed technique of isotope dilution in the analysis of stable oxygen isotope ($\delta^{18}O$) and carbonate clumped isotope (Δ_{47}) composition of surface-dwelling *Globigerinoides sacculifer* (0-25m habitual water depth) and sub-surface dwelling *Neogloboqudrina dutertrei* (50-70m habitual water depth) planktic foraminifera. The $\delta^{18}O$ value of foraminifera is a function of seawater $\delta^{18}O$ at equilibrium and the temperature of the surrounding where the organisms thrive. The evaporation process over the ocean prefers lighter oxygen (^{16}O) in the vapor state as salinity increases and vice versa in the event of precipitation. Our results show a significant correlation between $\delta^{18}O$ in seawater and surface water salinity. In contrast, the carbonate-clumped isotope (Δ_{47}) value is driven by the temperature alone rather than its surrounding fluid. The difference in the Δ_{47} value and the seawater $\delta^{18}O$ for *G.sacculifer* & *N.dutertrei* follow the evolution of temperature and salinity stratification in the BoB, and hence show the density stratification of BoB water during the past 25 kyr. A link between BoB hydrography and South Asian rainfall is suggested by comparing reconstructed BoB density stratification with the available high-resolution record of continental rainfall from multiple proxies.

Stable isotope records of fossil pollen in Lake Suigetsu, Japan, since the last interglacial

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Fossil pollen grains are preserved in many terrestrial sediments, often in a large quantity. Their potential as a material for stable isotope analysis have long been recognised (Loader and Hemming, 2004). However, difficulty in extracting fossil pollen grains at high purity was preventing the approach from being implemented for real. The development of a new technology called “flow cytometry” (or “cell sorter”, an instrument that can identify and extract each particle in suspension based on its optical characteristics such as fluorescence) provided us with the possibility (Tennant et al., 2013). Yamada et al. (2021) further improved the method, and finally realised routine extraction of fossil pollen grains at high purity suitable for isotope analyses (Omori et al., submitted).

We applied this new method to the varved sediments from Lake Suigetsu, Japan, and analysed stable isotope ratios of their fossil pollen. The sediments have one of the best age controls of the world supported by >800 radiocarbon determinations and varve counts (Bronk Ramsey et al., 2012; 2020), and thus can be precisely correlated with other palaeoclimate records (Nakagawa et al., 2021). We extracted >0.5 million fossil pollen grains from each target horizon, and submitted the pollen concentrates to pyrolysis mass spectrometry. The oxygen isotope ratios of fossil pollen varied in the range of 15-35‰. Although it is premature to draw any conclusion (at least at the moment of this submission) due to the still insufficient number of data, the fossil pollen isotope ratios of Suigetsu appear to follow roughly the same trends as the Greenland and Hulu Cave records. As the fluctuation range of the fossil pollen oxygen isotope ratio is similar to that of modern cedar pollen collected from across Japan, it is thought that the stable isotope ratios of fossil pollen reflect past environmental changes. Palaeoclimatic information from the terrestrial realms in which humans live can provide a key for investigating interactions among components of the climate system, and the stable isotope ratios of fossil pollen grains has potential to provide such information.

Bottom water oxygenation reconstruction East of Taiwan during the last 19ka based on benthic foraminifera

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Heinrich Stadial 1 (HS1, 18.2 – 14.7 ky) is usually associated with a decrease in global marine biological pump efficiency, one of the main reasons put forward to explain the 50 ppm increase in atmospheric CO_2 during this period. However, some recent studies have focused on the marine biological pump behavior at low latitudes during the ice age and have shown intensified primary activity particularly during HS1, making the decrease in the intensity of the marine biological pump unclear in these areas. This study is therefore aimed at constraining the efficiency of the marine biological pump in the subtropical northwestern Philippines Sea since the end of the LGM, a key region reflecting the large reservoir of marine carbon of the low latitudes of the North Pacific.
A multi-proxy study was performed on the sediment core MD18-3523 (EAGER campaign, East of Taiwan, 2972 m water depth), using XRF measurements, benthic foraminifera-related oxygen transfer functions, benthic foraminifera accumulation rates (BFAR) and associated paleo-primary productivity (pPP) and organic carbon flux to the sea floor (Jsf) proxies. The semi-quantitative and qualitative proxies allowed us to reconstruct an increase in oxygenation from the Bølling-Allerød to the Early Holocene that started with suboxic-dysoxic conditions during HS1 and ended in oxic-suboxic conditions during the Holocene. This study highlights the link between the increase in marine primary productivity and the low oxygenation conditions that favored the preservation of organic matter (and carbon) during HS1, suggesting the importance of the local mechanisms in the low-latitude global marine biological pump.

Session 196: Quaternary sedimentary-basins evolution: controlling factors and implications for future scenarios or past reconstructions

Sedimentary processes on shelves of volcanic ocean islands (Santa Maria in Azores archipelago): terrigenous versus carbonate production

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Cool- and temperate-water carbonate sedimentation in the shallow water realms of continental margins is relatively well documented. However, in volcanic ocean island settings, these carbonate factories are mostly unstudied. Present-day models suggest that in shelves of volcanic ocean islands, sedimentation is mostly restricted to volcaniclastic input, whether from cliff and stream erosion, or from explosive volcanism. However, a sediment-sampling survey around the shelf of Santa Maria Island in the Azores archipelago has shown that we probably need to change this paradigm.

Based on a set of 120 samples collected all around the shelf of Santa Maria Island (20-200m), we have seen a diverse heterozoan accumulation, composed of sand to gravel-sized biogenic skeletal components. These are mainly composed by bivalves, gastropods, echinoderms, bryozoans, foraminifera and polychaetes. Even nearshore (20-50 m), terrigenous particles only account only for 20%-50% of the total sediment. And as we move offshore, to the mid- and -outer shelf (50-200 m), carbonate skeletal particles constitute 80%-100% of the total sediment.

Being Santa Maria an old (~6 Ma) and volcanic inactive, low and dry island, with quite wide shelves (2-8 km), terrigenous input to its shelves is limited. Although wave energy is high in the North Mid-Atlantic, the relatively wide shelves attenuate them and cliff erosion is low. Therefore, in the inner shelf (0-50m), a mixed volcaniclastic- bioclastic sedimentation prevails. Below storm wave base terrigenous sediments seldom reach the middle to outer shelf (50-200m) and carbonate skeletal particles prevails.

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Contribution to the knowledge of the marine sedimentary cover of Madeira Island (Portugal)

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The SEDMAR Program of the Portuguese Hydrographic Institute aims to map the seafloor of the Portuguese margin. Within its scope, in May 2017, multibeam and sediment sampling surveys (down to 2000m deep) were carried out along Madeira Island margin. Twenty-eight surface sediment samples collected along an SW-NE segmented profile were textural and compositional analyzed for characterization of the sedimentary cover of the insular seafloor.

Bathymetric data allowed the identification of the shelf edge, locally placed at 140m deep, and the differentiation of two main geomorphological domains. The later geomorphic feature delimits the shelf, with a low gradient (<8°), from the slope that extends down to the 2000m isobath. The slope is crossed by a channel and several gullies and has a steep surface (>10°) down to ~1650m deep. The lower slope is a slightly inclined ramp (<10°).

The coarse fraction and the mean grain-size of the sediments decrease seawards. Sediments from the shelf have more than 70% of coarse-grained particles and exhibit an average size of 3.5φ-2.7φ (very fine to fine sands), while those deposited along the slope (except in the main channel) tend to have <70% of coarse-grained particles and a mean grain-size between 6.5φ (fine silt) and 3.3φ (very fine sands).

These sediments are mainly constituted by lithoclasts that are, based on the elemental analysis of the non-carbonated component, sourced by the erosion of the outcropping lithologies on Madeira Island. Silicate minerals (pyroxene+plagioclase+olivine) are dominant, while oxide minerals are present in small amounts. Ca-carbonate minerals, associated with the presence of bioclasts, were only detected in sediments collected >120m deep. This is in accordance with the spatial distribution of the Ca-carbonate content that shows a progressive increase along Madeira's shelf up to 18%, whereas in the insular slope its content is variable (14%-48%) without an evident distribution pattern.

Further work will focus on the in-depth study of the analyzed parameters, complemented by the identification and characterization of lithoclastic and bioclastic particles, to establish the morpho-sedimentary sectors and the prevailing deposition conditions in the two geomorphological domains.

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Morphotectonic and sedimentary evolution of Quaternary intermontane basins in the Apennines: the Colfiorito case-history (Umbria-Marche Apennines, Central Italy)

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The intermontane basins of the northern Apennines represent the sedimentary record related to extensional tectonics which has displaced the contractional structures since the Early Pleistocene. The Colfiorito basins system belongs to the easternmost alignment of the active normal faults, which is still active today. It consists of seven intermontane tectono-karstic basins in the Umbria-Marche Apennines, developed in a NW-SE direction at altitudes between 750 and 900 m. It therefore represents an excellent study case to understanding the Quaternary morphotectonic evolution of the area, made possible by the detailed geological surveys founded by the CARG project, the revision of the subsurface data (geognostic and geophysical surveys), the analysis of geomorphic features and the characteristics of the sedimentary record. The oldest evidence of this evolution is represented by the remnant land-surfaces disposed today at altitudes up to over 1300 m, testifying the first uplift phase of the Apennine ridge between the Late Miocene and the Pliocene. They are related to morphoclimatic conditions associated with large-scale areal erosional processes. The oldest sedimentary records are associated to the Early and Middle Pleistocene, cropping totally out only in the southern area of Cesi and San Martino, thanks to the current fluvial erosion. In the Colfiorito basin tectonic subsidence has played a predominant role and these units are buried underneath the more recent deposits of the Late Pleistocene. These are divided into large alluvial fans vanishing to the basin surface and thick stratified slope waste deposits, developed in different morphoclimatic and morphodynamic conditions. The sequence is closed by the Holocene deposits, fed by seasonal flooding with a fluvio-karst flow. Limited outcrops of older deposits, referable to the Middle Pleistocene, can be traced in the northern areas only inside the Dignano basin, where they are carved by the Late Pleistocene deposits, or on sub-flat surfaces displaced by the normal faults. Characterized by a NE-dipping stratification with recognisable conjugated structures orientated according to the main one, these faulted deposits revealed the constrain of the main fault bounding the Colfiorito basin to the North-East, postdating his influence in the morphotectonic evolution of the area.

Facies Analyses and Petrography of Volcaniclastic Deposits Associated with Kos-Nisyros-Yali Volcanism on The Bodrum Peninsula (MUĞLA / TÜRKİYE)

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The volcaniclastic deposit which is defined at the top of the stratigraphic sequence of the Bodrum peninsula (Mugla/Türkiye) in Western Anatolia, located along the western coastline of the peninsula. The pumice and glass shard- rich deposit which presents ~8 m thickness, is observed 1-1.5 meter below sea level. Base on limited definitions in the previous studies, this sequence is named as the Kos Plateau Tuff of the Quaternary Kos - Nisyros - Yali volcanic activity.

The internal structure of the deposit, which presents variable colors in yellow tones, forms mineral and glass-rich volcanic ash, accretionary lapilli, pumice lapilli and volcanic lithic fragments. The fragments of angular and rounded pumice (up to 26.5 cm long) consist of glass fragments - euhedral quartz – biotite – feldspar – plagioclase – sanidine phenocrysts. The angular volcanic lithics in the composition of trachyandesite – trachyte – andesite reaches a maximum of 17 cm in length. The maximum diameter of accretionary lapilli, identified at each level of the pyroclastic sequence, was measured as ~2 cm. Morphology of accretionary lapilli and glass splinters in volcanic ash present a sharp and plate-like morphology indicating a phreatomagmatic eruption with a vapor (wet) phase. Detailed examinations carried out on a microscopic scale, revealed the presence of shell fragments, carbonization of wood components and highly argillized components in the volcaniclastic deposit.

Isopach and thickness maps were created based on the numerical values of pumice and volcanic lithics, which are the main components of the pyroclastic succession, it has been determined that the grain size increases with distance from the volcanic eruption center. Contrary to normal conditions, it offers grain size, the presence of irregularities in the sequence observed at the field scale and the presence of shell fragments belonging to the seafloor identified at different levels of the volcaniclastic deposit led us to question the existence of a tsunami-like geological event during the last Kos - Nisyros - Yali volcanic activity.

Reconstructing the Homo sapiens settlements dynamics in Eastern Morocco through the MSA & LSA stratified open air sites

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Data from *Homo sapiens* MSA-LSA occupations in Eastern Morocco are well-known from cave and rockshelter sequences (e.g., Ifri n'Ammar, Rhafas, Taforalt). In contrast, open-air settlement dynamics has been little studied so far, and the only data currently available come from disperse and unstratified lithic scatters.
Systematic surveys and archaeological excavations at the Aïn Beni Mathar – Guéfaït basin (Jerada province) have been undertaken during the last sixteen years. Our bilateral Spanish-Moroccan research project has allowed us to discover several stratified open-air localitieswith different archaeological horizons including lithics and faunal remains associated to the Middle Stone Age (MSA) and Late Stone Age (LSA).
These new sites are located in the Sahb el Gahr – Swiwina plain and the Tahya-Oued Za River area, mostly on slopes and exposed surfaces of riverbanks, nearby springs, and always associated with areas rich in biotic and abiotic resources. The palaeoecological reconstruction shows open semidesert environments with vegetation concentrations related to water points and lakes, very similar to the current landscape.
From a technological point of view, the MSA sites are characterized by homogeneous flake assemblages from

Levallois and discoidal knapping strategies but also opportunistic ones. Retouched tools are abundant (mainly denticulates and scrapers), and “Aterian” assemblages with tanged pieces and bifacial foliates have been also documented. The LSA sites show a higher density of lithic remains composed of standardized laminar and flake assemblages showing the typical technological attributes characterizing the Iberomaurusian culture. These assemblages are associated to structured hearths that can be interpreted as domestic areas.
In this paper, we present new data from the systematic excavations of the Sahb el Gahr 1 and 2, Oued Charef and Tahya 3 MSA sites, and from preliminary test pits at Tahya 4 and Ain Tifirassine LSA sites. Moreover, we will introduce our methodology of excavation including a new software developed for computerizing, automating and systematizing field data recording.
These interdisciplinary results provide a novel overview of the MSA-LSA dynamics in open-air contexts, focusing on the subsistence strategies, the mobility across the territory, and the type of occupations depending on the available resources in the area.

The Early Pleistocene in the Lake Garda area

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The reappraisal of well-known Early Pleistocene sites of the Lake Garda area with modern analyses and the study of new drillings allow to improve our knowledge about the Early Pleistocene of Lake Garda area. On the western side, in the Valsabbia sector an ancient lacustrine basin with a regressive succession from fine-grained deposits with travertine to conglomerate at the top has been chronologically constrained to the pre-glacial Matuyama by the occurrence of M. meridionalis (2.5–0.98 Ma) and reverse magnetization. Near Ciliverghe, in the proximal plain SW of Lake Garda, a 30-m deep core with shallow marine deposits provided Reticulofenestra asanoi (1.14–0.91 Ma) and a normal to reverse polarity (bottom to top) referred to the Jaramillo and the late Matuyama, respectively. Stratigraphically above, in the nearby Ciliverghe hill, the core succession is completed by glacial and fluvioglacial deposits, also bearing reverse magnetization. The same polarity is documented in glacial and fluvioglacial deposits also along the Chiese River succession, north of Ciliverghe, and in glaciolacustrine deposits at Salò. At East, reverse polarity has been also retrieved in fluvioglacial deposits at Sirmione. On the whole in the Lake Garda area, as in other basins of the Alps such as Leffe, the pre-glacial Early Pleistocene is documented by long-standing lacustrine basins, which end with a high-energy event ascribable to the onset of major Pleistocene glaciations at 0.9 Ma. The accommodation space required to develop the lacustrine basins is possibly related to local tectonics subsidence. In the plain, the whole Ciliverghe sequence documents that the Lake Garda area passed from shallow marine to braidplain sedimentation when the first major glacier faced at the outlet of the Lake Garda Valley at 0.9 Ma. Remnants of this first Early Pleistocene glaciation, including all typical facies of the glacial depositional system, are sparse along the western sector of Lake Garda because of the recent tectonic uplift this part with respect to the eastern sector. On the eastern side, just a small and isolated outcrop in the Sirmione peninsula documents the transition from a glacial proximal outwash plain to an interglacial braidplain system.

The issue of land subsidence in coastal-alluvial plains: a new approach from the Campania Plain (southern Italy)

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One of the main causes of the natural subsidence of the alluvial/coastal plains is the poor geomechanics characteristics of the Holocene deposits that filled them, i.e. silt, clay, and peat. The contribution of these sediments to the phenomenon was assessed for the alluvial plain of the Volturno River (southern Italy), which is characterized by medium-high subsidence rates in the order of 15-20 mm/yr. This area benefits of a unique stratigraphic condition that allows a good understanding of the main drivers of subsidence: the Holocene sedimentary sequence is underlined by a continuous stratigraphic marker, the Campanian Grey Tuff (CGT), a volcaniclastic unit vented by a 39 ka Campi Flegrei eruption, from the Tyrrhenian side of the Campania Plain. The sediments above the CGT surface can be classified as fine-grained soil with high compressibility and low strength from a geotechnical point of view. These layers may experience two different types of consolidation: i) primary consolidation, due to a variation of effective stresses; ii) secondary consolidation, the deformation of soil under steady stresses. Moreover, the peaty intercalation and the presence of organic matter led to high values of the coefficient of secondary compression.

The above considerations highlight the importance of providing not just geological modeling but also an accurate geotechnical characterization of the different layers, in order to understand the mechanism behind the variation of the subsidence rates. In the study area, the latter was carried out by processing the CPT tests, and obtaining different geotechnical parameters. Usually, soils like clay, silt, or sand have geotechnical parameters that vary according to the lithology; nevertheless, among the same lithology it is not unusual to observe different behavior. Comparing the Soil Behavior Type Index, Ic, with the different lithologies and the inferred depositional facies, it was highlighted the strong relationship between Ic and the depositional facies. In this way, facies analysis and geotechnical characterization allowed on one hand to highlight the natural causes of subsidence in the Volturno alluvial and coastal plain and, on the other hand, to improve the stratigraphic characterization by using CPT tests.

Stratigraphic and tectonic evolution of two wedge-top basins (Sciacca-Ribera area, south-western Sicily) during the early Pleistocene.

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The area comprised between Sciacca, Caltabellotta and Ribera, in the south-western Sicily, represents a very important sector to analyse the late Neogene and Quaternary evolution of the Sicilian foreland-basin-system. In this area, a fragment of the Sicilian Fold and Thrust Belt (FTB) crops out, mainly constituted by south-verging tectonic units of Meso-Cenozoic carbonate and open-shelf clastic successions (Saccense Domain), unconformably covered by middle Miocene to Pleistocene pelagic, clastic and terrigenous deposits. These latter could be considered as wedge-top basin deposits progressively involved in the Sicilian FTB. Near Ribera area late Miocene to Quaternary marine sedimentary successions, belonging to the Gela Thrust System (GTS), crop out and appear to be remarkably affected by the most recent deformation phases of the Sicilian FTB evolution.

Two sedimentary sections (Nadore and Maienza) located in different tectono-stratigraphic setting were analysed using a multidisciplinary approach, through sedimentological, micropaleontological, stratigraphic and structural analyses.

The Nadore section, located north of the Sciacca town, is composed by a succession of about 50-70 m of hemipelagic clayey-marls and turbiditic sandy-silts, evolving to sands and resedimented calcarenites upward. This succession, belonging to the marly-arenaceous Formation of Belice, has been dated to the late Piacenzian-Gelasian interval and appears strongly deformed, indicative of infra- and/or post-Gelasian compressional tectonic pulses.

The Maienza section, instead, located south-east to the Ribera town, is a 50 m thick succession composed by hemipelagic dark gray and brownish marly clays with resedimented quartz, gypsum and reworked planktonic foraminifera, evolving to pelagic and hemipelagic light gray marls, silty clays and calcilutites upward, with a thin sandy-conglomerate level on the top. The evidences collected in this latter stratigraphic record, ascribed to the Monte Narbone Formation (late Pliocene - early Pleistocene), indicate that this basin recorded active tectonic event up to the middle-late Gelasian and by standstill of the tectonics during the Calabrian stage.

Therefore, the target of this work was to compare the depositional and tectonic dynamics of two wedge-top basins during the early Pleistocene, in order to obtain additional information about the recent evolution of the southern Sicilian FTB.

Session 197: How can archaeology, palaeoecology, traditional knowledge, and more-than-human approaches contribute towards a more sustainable and culturally informed future?

Reconstructing Indigenous-managed landscapes through changing climates in southeast Australia

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In Australia, the recent unprecedented wildfires of 2019-2020 sparked debates around managing fuel loads in a context of climatic warming and increased fire risk. Ethnohistorical evidence suggests that for tens of millennia, Indigenous peoples of Australia practiced cultural burning, which limited understorey woody growth, resulting in less intense wildfires. Therefore, Indigenous cultural burning has been raised as a potential management tool for mitigating against climate-driven catastrophic events. However, one of the barriers to the implementation of cultural burning in southeast Australian is uncertainty around its spatial extent, frequency and impacts on biomass (i.e. fuel loads) prior to colonial settlement in 1788.

The quantification of past land cover is needed to address such debates and fill this important knowledge gap. Pollen is the key proxy to track past vegetation changes, but pollen spectra suffer from some important biases e.g. taphonomy, pollen productivity, dispersal capability. Many pollen records are dominated by pollen from a few high pollen-producing plant taxa, which mask the less producing taxa. In effect, there is a non-linear relationship between pollen percentages and plant cover. Estimating past vegetation cover from sedimentary pollen composition requires to correct for productivity and dispersal biases using empirical-based models of the pollen-vegetation relationship (e.g. REVEALS). Here we present an application of the REVEALS model on multiple pollen records (n=39) throughout the Holocene across southeast Australia.

We provide the first regional quantification of land-cover changes and we link emerging findings to changing climatic conditions and evidence of human activity across the region. We reveal predominantly open landscapes throughout the Holocene, probably characterised by wildfires of lower intensity than present day due to lower fuel loads. Our deep-time data reaffirm Indigenous narratives about cultural burning, highlighting the need to embed these practices for sustainable wildfire management.

Using novel biogeochemical and modelling techniques to reveal the past extent of key Indigenous food plants in southwest Victoria, Australia.

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Since the onset of the Holocene, changes to a landscape's vegetational structure have sometimes been indicative of cultural land usages like forestry and agriculture. Modelled pollen-based vegetation reconstructions, using, for instance, the Regional Estimates of Vegetation Abundance from Large Sites model (REVEALS), have quantified regional vegetation compositions and dynamics. REVEALS is commonly used to quantify only the most common taxa, whereas the taxa of cultural importance for Indigenous peoples, including many indicator plants with morphologically cryptic pollen (unidentifiable using traditional visual identification on a biological microscope), currently lack quantified reconstructions.

Here we studied *Microseris,* an Australian Indigenous staple food plant (Cichorioideae subfamily, Asteraceae Family, known to Indigenous peoples as "Murnong"). *Microseris* abundance and spatial extent can indicate complex pre-colonial Indigenous land and food-cultivation practices. Abundant *Microseris* was described anecdotally across southwest Victoria in early colonists' journals, suggesting that it was much more widespread than its modern post-colonial distribution. However, these descriptions may be subject to prejudices and biases in 17th and 18th-century colonial perceptions, requiring modern objective scrutinization. Its suggested widespread occurrence in the past makes *Microseris* an excellent taxon for regional-scale modelling, but hitherto the cryptic morphology of the Cichorioideae subfamily has limited the quantification of species within the subfamily. Here we present a method for the regional quantification of *Microseris*, combining biogeochemical techniques with pollen-based, landscape-level plant reconstruction models.

The chemistry of sub-fossil Cichorioideae pollen, obtained using Fourier-Transform Infrared (FTIR) spectroscopy, has been compared with a modern library of chemical spectra of native Australian Cichorioideae pollen, including *Microseris*. The modern library samples, like the sub-fossils, underwent complete sub-fossil pollen preparation procedures , allowing comparable species-level identification of sub-fossil Cichorioideae pollen. The chemotaxonomic information derived from FTIR will aid in the identification of sub-fossil *Microseris* and allow subfamily modelling using the REVEALS algorithm. *Microseris* reconstructions will help paint a picture of the complex Indigenous-managed foodplant-landscape that may have persisted since the first human settlement of Australia, as far back as 65,000 years ago, which should be considered in the management of the environments where *Microseris* was -and still is- found.

Living Along the River: Human resilience to fluvial environments in Prehispanic and contemporary Central Nicaragua

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Water is a key element in the interplay between humans and their social and environmental relationships, ultimately shaping landscapes and the movement of people, goods, and ideas. Located along the Central American Dry Corridor, central Nicaragua is highly susceptible to hydroclimatic fluctuations. Currently, droughts and floods are impacting subsistence economies of rural human communities by threatening agricultural activities, damaging infrastructure, forcing migrations, and contributing to the loss of life. This presentation shows a case-study of human resilience to a river valley, through a multi-scalar analysis of archaeological and paleoenvironmental data spanning the last 1,200 years, interpreted in collaboration with local rural communities. The geoarchaeological analysis of the Roberto Amador site (RA), demonstrates the occurrence of floods during its prehispanic occupation (AD 900–1250). Human responses to alluvial events is evidenced by the differentiated use of the site topography and of the alluvial terraces depending on the likelihood of localized flooding. The inundation that affected the site around AD 1250 ultimately likely led to its abandonment, suggesting that the human communities living in the Mayales River Valley (MRV) used adaptive settlement strategies to select, adjust to, and relocate when exposed to major fluvial changes. By comparing the archaeological data from RA to the 1,200 yr paleoclimatic records produced by the authors for central Nicaragua, it is possible to correlate this inundation to regional hydroclimatic developments. We have been documenting the local knowledge on water through interviews, participative observation and outreach activities. This evidenced how modern land-use strategies, combined by climatic change, are highly affecting the water quality and biota of the Mayales River, alongside demonstrating the deep environmental understanding fostered by the MRV rural communities. This study shows that prehispanic adaptation strategies in the MRV were linked to people's detailed understanding of its alluvial landscape and the river's behavior. We argue that archaeological research, combined with local knowledge, could contribute to envisioning a more inclusive approach for planning sustainable water and land-use practices in central Nicaragua.

Pollen and non-pollen palynomorphs (NPP) as a tool to reconstruct local land uses practices during the Medieval and post-Medieval periods: case studies from the Ligurian Appenines, North-Eastern Italy

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Palynological and non-pollen-palynomorphs (NPPs) analyses at several sites located in Trebbia valley, eastern Ligurian Appenines (north-eastern Italy), have been carried out during the last years by the Laboratory of Archaeology and Environmental History (LASA) of Genoa University and more recently in the frame of the research project "ANTIGONE - Archaeology of sharing practices: the material evidence of mountain marginalisation in Europe (18^{th}- 21^{st} century AD)" (ERC Stg 2019).

The main aim was the reconstruction of main vegetation dynamics and the identification of biostratigraphical information about the local management of environmental resources during medieval and postmedieval periods. Thanks to additional information from archaeological and archival sources, as well as from the observation of the present vegetation cover, these studies clarified how different kind of land-use now completely disappeared (woodland management, permanent and temporary "slash-and-burnt" practices, transhumance systems, etc) changed through time, also in relation to the organisation of local social groups and the transformation in the access right to common-lands. Furthermore, it was possible to underline the ecological, cultural and economic consequences of these changes. In particular, based on specific features of palynological diagrams, it was possible to conclude that - compared to the post-cultural phase - all the sites were characterized by: (1) lower pollen percentages of trees; (2) higher pollen amounts of herbs and shrubs, typical of landscapes with a predominance of open areas; (3) higher percentages of anthropogenic pollen indicators; (4) higher values of palynological richness and thus greater biodiversity; (5) higher amount of microcharcoal fragments in most case studies.

Thanks to an interdisciplinary research team (botanists, palaeoecologists, historians and archaeologists), the results of our investigations demonstrate the necessity of a long-term prospective in environmental reconstructions for the preservation of the cultural landscape. This research also represents a contribution to issues of habitat management and nature-conservation policy.

Transdisciplinary investigation of the vulnerability to climate change of Southwest Madagascar

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Climate models have shown that there will be an increased susceptibility to drought in the future for semi-arid regions. Using a vulnerability framework, this paper assesses the vulnerability of the social-ecological systems along the transect of rainfall gradient in southwest (SW) Madagascar through a transdisciplinary approach, that combines palaeoecological data with local ecological knowledge (LEK) from household surveys. We used existing fossil pollen data from the region alongside analysis and review of regional climate records of the last 2000 years to investigate ecosystem vulnerability to changing climate. The pollen records show that in the face of a drying climate, the landscape has been affected differently in the past and will likely become vulnerable to changes when combined with land use changes in the future depending on availability of adaptation options for communities. Wetter sites, in the northern part of the region, were less sensitive to drought possibly due to the availability of water and the heterogeneity of the landscape offering possibilities of livelihood diversification for nearby communities. Drier sites, in the southern part, are more ecologically vulnerable particularly with an increasing land use as these will lead to disappearance of dry-adaptive taxa and degradation of existing biodiversity as reflected at the near present period. Although some of the adaptations to climate change (CC) might be beneficial in the short-term, adaptation such as migration might be detrimental to biodiversity in land-constrained areas where conservation actions are a priority. Improving the resilience of the landscape in drier sites to CC by focusing on plant functional type as well as monitoring land use is urgently needed while focusing on managing land use within the dry forest is necessary to reduce potential vulnerability in the future.

Settling the debate on anthropogenic origins of high-elevation grasslands in the Nilgiris, southern India - implications for ecosystem management

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Ecologists have puzzled over the existence of forests *(shola)* and grasslands in close spatial association in the high-elevation Nilgiris for over a century. A number of authors have speculated about the grasslands that seem to be in apparent 'inequilibrium' – either supporting 'natural bi-stable climax' or 'grasslands are sub-climax maintained by humans' (through fires). In an ancient peatland at Sandynallah valley (>50,000 years old), a number of palynological and stable isotope-based paleoecology investigations have established the antiquity of grasslands here, with high numbers of grass pollen observed in peat even as old as 35,000 years. We conducted pollen investigation on a peat-core with high-resolution chronology from the same valley, and see evidence for the continuous dominance of grass pollen (~40% total pollen) from surface to 1.3 m depth (a span of 38,000 years), and at 3.46, 3.57 m depths, beyond the radiocarbon limit (>50,000 years, AMS). Cyperaceae pollen have continuous presence, increasing towards the surface, with the lowest abundance (5%) at the bottom of the profile, indicating beginnings of peatland formation. We see herbaceous pollen taxa that co-exist with grasslands on the slopes throughout, from Gentianaceae, Apiaceae, Ranunculaceae and Valerianaceae families, also indicative of grassland persistence. Although *shola* forest members from dominant family Lauraceae are not preserved in pollen records, we see *Michelia, Olea glandulifera, Glochidion, Daphniphyllum, Rapanea, Ilex, Elaeagnus, Viburnum, Celtis* and *Meliosma* with some of these taxa appearing throughout the profile. In general, arboreal taxa exhibit higher diversity in the Holocene, typical of wetter conditions. We also see swamp flora *Eriocaulon, Xyris, Impatiens, Laurembergia* and *Commelina* and arid markers *Artemisia* and Amaranthaceae/Chenopodiaceae with vegetation dynamics responding to climatic changes. Through these results, similar to other researchers before us, we are able to show dynamic *shola*-grassland vegetation through time, consistent with other global vegetation mosaics. It is important to note that early misunderstanding of these grasslands led to widespread planting of commercial woody species eucalypts, Australian wattle and pines, which together cover >40% of the reserve forest area on the plateau. These and other alien invasive species threaten this ancient grassland ecosystem which has been subject to historical mismanagement.

Stratified landscapes as information pools for sustainable land management: the case of Porto Selvaggio (Nardò, Lecce – Italy).

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Regione Puglia (the Region of Apulia), through the *Piano Paesaggistico Territoriale Regionale* (PPTR), has begun to make progress in learning about the human-nature relationship that created the current landscape. Archaeological research had a central role in recognizing the practices that ensured the stability of the territorial resources and the growth of the communities over time. In the landscape we can see the traces and models of the use of stratified territories as tangible and intangible heritage and identify the "Structural Invariants" of the territory that ensures a development balanced between the environment and the needs of the community. Thus, a wrong or partial interpretation of the structural invariants provides inadequate tools of territorial planning.

Considering the Technicity and Territoriality concepts developed by Raffestìn and adopting them in the elaboration of the PPTR, Museo della Preistoria di Nardò (LE) is testing the possibility of reconstructing the cycles of territorialization preserved in the prehistoric sites of the Natural Regional Park "Portoselvaggio-Palude del Capitano" (Nardò-LE) and Salento. In these regions, the richness of Paleolithic sites allows us to cross-check techno-cultural, hydro-geomorphological and paleoenvironmental data and to reconstruct the strategies used by human beings to organize the territory through time.

Indeed, the data from the Paleolithic contexts suggest that those human groups had a broad range of technical and geographical knowledge but with low environmental impact and through it organized the territory systematically. However, the theoretical system that led to the interpretation of the long-term processes and use of the territories in the PPTR has only been able to recognize this ability starting from the Neolithic "Revolution". This understanding results in the exclusion of much of the human history in Apulia and of the past resource management practices. The underestimation of the organizational knowledge of the Paleolithic groups is likely linked to fewer and more subtle traces that characterize the life of nomad groups and possibly to our inclination to attribute greater importance to evidence related to permanency.

Preliminary results of the research indicate the existence of at least five cycles, continued inter-disciplinary studies will allow us to better understand this developmental framework.

Session 204: Late Quaternary Faulting and Earthquake Geology in volcanic areas

Challenges and perspectives of volcano-tectonic studies for the analysis of faulting and earthquakes in active volcanic areas

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During the last three decades, much effort has been made in the understanding of the structural evolution of volcanic systems. These studies have been mostly devoted to the analysis of volcano-tectonics interplay, volcanic eruptive and lateral collapse hazard, and exploration of geothermal reservoirs and epithermal ore deposits. Nowadays, an increasing number of works and research projects recognized the importance to study the peculiar behaviour of volcanic systems and volcanic successions also for the analysis of seismic events and coseismic-aseismic surface ruptures.

Regional faults and stress field, contrasting rheology of volcanic successions, basement inherited structures, load of the volcanic pile, and geometry and dynamics of the plumbing and hydrothermal systems have been identified as the main factors conditioning the structural architecture of volcanic systems. These factors play a major role in faulting, migration of the magma toward the surface, opening of eruptive fissures, and volcanic spreading, all of which may generate hazardous seismic activity.

Despite the scientific, economic, and social importance of "Earthquake Geology" studies in volcanic areas, reliable volcano-tectonic and structural models are lacking or incomplete for many of the major active volcanoes worldwide. Also, morpho-structural, structural, neotectonics, geological fieldwork and paleoseismological methodologies (and their integration with geophysical and geodetic analysis) developed in non-volcanic areas may be inadequate when studying volcanic systems, because of the complex interaction among the abovementioned factors. Finally, the large volumes of volcanic products commonly emplaced on volcanoes can cover up partly or completely tectonic and volcanotectonic structures, making the study of surface faulting and ruptures even more difficult.

An overview of complex volcano-tectonic settings and methodologies for their study is presented, with the aim to provide adequate conceptual tools for the analysis, from the "Earthquake Geology" perspective, of ground deformations, faulting, fracturing, opening of eruptive fissures, and gravitational instability of active volcanoes. Future challenges in the understanding of the relations between tectonic and volcano-tectonic Quaternary faults, coseismic and aseismic surface ruptures, magmatic activity and seismic events in volcanic areas, and their importance for civil protection and land use plans, are also discussed.

Multidisciplinary Approach for Capable Fault system study at Ischia Island, northern sector of Mt Epomeo (MACFI project): preliminary results.

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The study's aim is constraining the source characteristics of the Casamicciola Terme active and capable fault system at Ischia Island for providing a contribution to the local seismic hazard. Ischia is an active volcanic island on the NW side of the Gulf of Naples and belongs to the Campanian volcanic province. On August 21st 2017 a Md 4.0, 1,5 km depth volcanotectonic earthquake reactivated the Casamicciola Terme capable fault. The epicentral location of the relevant earthquake in the last three centuries, in particular the ones of 1796, 1828, 1881, and 1883, are systematically confined within few km^2 in Casamicciola Terme area. Here, a clear stratigraphic and morphological trace is preserved and represented by the graben at the base of the N flank of Mt Epomeo, which formed as the result of Holocene extensional tectonic deformation. The Mt. Epomeo (787 m a.s.l.) uplift is the final stage of the resurgence phase that created the main morphological structure emerging nowadays, with an average rate of ca. 3 cm/yr in the last 30 kyr. The Mt. Epomeo is clearly asymmetric, with a maximum displacement on the N flank linked to an E–W normal fault system where all the significant seismic activity is centered.

The MACFI project consist of a multidisciplinary approach, including:

i) a geophysical survey of the 2017 earthquake epicentral area by 3D Deep Electrical Resistivity Tomography with three ERT profiles across the Casamicciola Terme graben; ii) a drone aerial survey with a LiDAR (Light Detection and Ranging) scanner generating a 5-10 cm resolution DTM, and a radiometric thermal camera areas, for identifying the morphological and thermal signature of faulting and progressive offset along primary surface ruptures along the southern portion of the Holocene graben; iii) the occurrence of directional amplification effects as an effect of the fault activity and rock fracturing at depth.

The combined aerial LiDAR and thermal remote sensing by drone allow to map with unprecedented precision the surface traces of the main and minor faults and fractures along the southern portion of the Holocene graben, and to identify possible correlations with the ascent of geothermal fluids.

Earthquake Environmental Effects on Mt. Etna: ESI-07 scale isoseismals, intensity-attenuation relationships and perspectives for seismic hazard assessment

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Earthquake Environmental Effects (EEEs) are macroseismic data that can be effectively integrated in the evaluation of past seismicity, and to depict possible scenarios of earthquake-induced effects. EEEs are particularly effective in the setting of the Mt. Etna volcano, where seismic events cause extensive surface faulting, typically strictly related with building damage. We analyze a dataset of 53 selected earthquakes occurred on the Etna flanks, since year 1865 to present-day, evaluating their ESI-07 (Environmental Seismic Intensity Scale, 2007) macroseismic field. We collected data directly in the field for the latest two strongest earthquakes (i.e., the Dec. 26, 2018, Mw 4.9, Fleri; and the Oct. 29, 2002, Mw 4.4, Santa Venerina eqs.). The main EEEs found are ascribable to surface faulting and ground breaks, with some minor landslides and drywall collapses, reaching an epicentral intensity between VII and X ESI-07. We compare our ESI-07 intensity results with the macroseismic data measured with the European Macroseismic Scale 1998 (EMS-98) for every earthquake in the dataset. We notice a striking disagreement between ESI-07 and EMS-98 intensity for the latest events (e.g., the 2002 and 2018 events). Furthermore, whereas the ESI-07 intensity for similar earthquakes along the same fault remained constant over time, the EMS-98 intensity has decreased from X to VIII in recent years. We argue that the intensity of the damage-based macroseismic scales might be affected by the new reinforced concrete structures and the introduction of new building codes, resulting in a decrease of EMS-98 intensities for earthquakes occurred in the last decades. The analyzed data allow us to suggest that the ESI-07 scale provides better macroseismic information of earthquakes generated in the Mt. Etna volcano-tectonic environment, where building damage is mainly located along the trace of surface faulting. As already observed at Ischia Island, the ESI-07 scale seems to provide a more time-invariant descriptor of the shallow-focus volcanic earthquakes effects, allowing a consistent comparison of other local seismic events occurred in the last centuries. Combining the ESI-07 scale with the EMS-98 scale can lead to a better description of all the earthquake's effects and as a result a better seismic hazard assessment.

Understanding Holocene fault slip-rates along the Casamicciola Terme graben, Ischia, Italy

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We conducted new UAV Lidar mapping, geomorphic, stratigraphic, and structural analyses along the 2 km long, E-trending, Casamicciola Terme Holocene graben, which follow the base of the 800 m high Mt Epomeo range front, in the N part of the Ischia Island, and is regarded as the source of the local damaging seismicity.
We used UAV Lidar DEM at 10 cm resolution in order to map the graben capable normal faults and the sequence of the displaced marine terraces preserved in their footwall and hangingwall. This allow us to identify in detail the primary surface ruptures accompanying the August 21, 2017, Md 4.0 and July 28, 1883, Mw 5.2, earthquakes. We defined a new stratigraphic model of the graben area based on 25 available drilling data calibrated with 2 new stratigraphic boreholes at Piazza Maio and Grande Sentinella sites.
Our new data, and comparison with available radiocarbon dating of the marine terraces along the N coast of Casamicciola and Lacco Ameno, and Ar/Ar dating of the Fundera lava flows, allow to constrain Holocene slip-rates for the synthetic and antithetic faults bounding the epicentral area of the strong 2017, 1883, 1881 and 1828 earthquakes. The S dipping fault at the S border of the Gran Sentinella terrace shows a slip-rate of ca. 6 mm/yr during the Late Holocene. The two parallel synthetic faults at the N-border of the Mt Epomeo slope show a cumulative slip rate of 26 mm/yr. The E-trending, N-dipping faults between Piazza Maio and the Montecito fumaroles represent one of several splays of the master fault responsible for the Holocene uplift of Mt Epomeo; which in turn is the source fault of the strong earthquakes occurred historically in the Casamicciola Terme and Lacco Ameno sector of the Ischia Island.

Evaluation of the earthquake environmental effects produced by the 1920 Xalapa earthquake, through the use of the ESI-07 scale

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The Trans-Mexican Volcanic Belt (TMVB) is an active continental arc related to the subduction of the Cocos and Rivera tectonic plates under the North American Plate. It is located in the central part of Mexico, where more than 50% of the total population of the country is concentrate. The TMVB is characterize by the presence of different systems of active crustal faults that are responsible for several destructive historical earthquakes, among which the Xalapa earthquake that occurred on January 3, 1920 with a magnitude of 6.4 stands out.

Even though the Xalapa earthquake represents the second deadliest earthquake in the history of Mexico after the 1985 Michoacan earthquake, there is still uncertainty concerning the location of the fault source and discussion about the gradient intensity in the affected area. some works have been carried out based on descriptions of architectural damages using different intensity scales (Cancani and Mercalli). However, the use of these scales is limited by the poor distribution of the population in this area at the earthquake time.

Analysis of historical documents, fieldwork and interviews with chroniclers and inhabitants of the area, associated with the analysis of digital elevation models and aerial photographs led us to obtain a new precise inventory of the location and description of all the architectural and environmental effects caused by the seismic event. In this work, a new isoseismic map is proposed where the epicentral intensity of the earthquake and the macroseismic field are precised, from the evaluation and classification of the earthquake environmental effects (EEE), through the use of the Environmental Scale Intensity ESI-07.

Analysis and 3 D Model of the Seismic Swarm of the Parícutin-Tancítaro Volcanic Region (PTVR) in Michoacán, Mexico 2020.

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The geology of the state of Michoacán is characterized by the subduction process of the Cocos Ocean Plate under the North American continental plate along the coastline actively occurs. This geodynamic process constantly generates tectonic activity linked to seismicity and volcanism, on the coasts and interior of the state. In fact, it is no coincidence that two of the most important historical volcanoes in Mexico are located in this area, they are: the Jorullo Volcano (1759-1774) and the Parícutin volcano (1943-1952).

The Parícutin-Tancítaro volcanic region is located at southwest of the Michoacán-Guanajuato volcanic field. In this region, seismic swarms have been recorded in 1997, 1999, 2000, 2006, 2012 and recently in 2020, 2021 and 2022. Our study show a spatiotemporal and statistical analysis of the data of the 2020 swarm and analize the possible correlation with those of the years 2021 and 2022.

We have relied on the data available and geolocated by the Mexican National Seismological Service (SSN, Mexico). The spatial tendency (vertical and horizontal) of the hypocenters was analyzed, as well as their distribution over time, comparing their behavior with the available information of seismic swarm events occurred in the same region.

In this work a 3D model is presented, which allows us to observe the evolution of the seismic swarm at different depths. Seven linear groupings are distributed in a focused manner under the Parícutin-Tancítaro Volcanic Region. The vertical and lateral spatial migrations of the hypocenters suggest the controlled rise of magma forming dikes and sills respectively, with a finite supply of material from a deeper reservoir.

Monitoring underwater volcanic degassing using Exail (iXblue) SeapiX volumetric sonar

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Volcanic gases are a main trigger of explosive eruptions, but the largest amounts are emitted through passive, non-eruptive, degassing during quiescence. It is thus necessary to accurately map bubble clouds, and to monitor their dynamics, to reduce volcanic risks. We present results from near-surface geophysics of sedimentary deposits and water column gas seepage at the Laacher See (Eifel, Germany), using iXblue Echoes high-resolution sub-bottom profiler and Seapix 3D multibeam echosounder. Backscatter profiles of water column elements distinguish gas bubbles and fishes and highlight several bubble plumes. Target Strength (TS) of bubbles is centered around -70 dB, suggesting they are of very small size (35 µm), much smaller than observed elsewhere using single beam echosounders. This would explain why, in the same spot, we did not observe any gas bubbling using camera mounted on ROV. Recent measurements at the nadir of a gas flare, in static positioning, using the steerable mills cross multibeam capability of the SeapiX, offered a 4D observation of the gas bubbling. It also provided an equivalent TS of the bubbling we observed two years earlier. We will also present CO_2 flow rates that were also extracted from backscatter of gas bubbling in 4D. These calculations are currently being constrained using different backscatter models and represent the last technical aspect before developing an efficient early warning system. Meanwhile, Echoes 10 000 provides high-resolution paleoenvironmental reconstruction using 3D modeling of remobilized materials, and gas diffusion through the sediment. Fusion of all geophysical data using Delph Roadmap allows 3D modeling of gas flare dynamic from 40m in sediment to water-atmosphere interface. Our scientific approach contributes to improve forecasting of volcanic and limnic eruptions and participates to improve early warning systems by constant collaborations with academic research.

Session 205: The environment background and human adaptations during the transition or shift from archaic humans to modern humans in East Asia

Environmental change and human adaptations in China between 125 and 30 ka.

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The main driver of environmental change between 125ka and 30ka is outcome of the strength of the East Asian monsoonal system versus the Siberian weather system. More specifically, this affects China in three ways: first in North China and the Tibetan Plateau, oscillations between cold, arid or semi-arid conditions and more temperate intervals that opened up corridors for immigration from outside and allowed expansion to the north; second, in South China, variations in the extent of sub-tropical rainforest versus more open woodland which would also have favoured population movements; and thirdly, the distance from the sea off the East China coastal shelf that affected the depth of penetration of monsoonal rain. These three factors combine to produce a complex picture of faunal, floral and population response.

Assessing human adaptations in this period is harder because of the lack of faunal and floral evidence from occupation sites. Nevertheless, we can detect the use of starch plant resource (as in other regions); some evidence of specialised hunting strategies; greater use of hafting and composite tools; and greater curation of lithic resources. In north China, the main adaptations are probably social, and are shown in the development of extensive social networks indicated by a common use of ornaments and ochre over an enormous area covering the Altai Mountains, Transbaikalia, Mongolia and north China. These shared items would have helped sustain viable information, social and mating networks that supported human populations in a hostile and harsh environment.

Environment Conditions Affected Arising and Dispersal of Modern Human in the North China and Mongolian Plateau

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Currently, undisputed evidences of modern humans and modern human behaviors from the North China started to appear around 40 ka, while before that, archaic humans with diverse morphological traits and behaviors widely dispersed. During the conversion from archaic humans to modern humans, environment change might have played an important role. However, we still know very little about it. Here we report the results of paleoenvironmental reconstruction from Daihai Lake (a 48-m long continuous sediment core) in the southern Mongolian Plateau, covering the past 80 ka when archaic humans disappeared but modern humans emerged in this region. Based on analyses of *n*-alkanes and hydroxy glycerol dialkyl glycerol tetraethers (OH-GDGTs), two proxies of plant productivity and lake level change, we find that proxies values were very low during 74-50 ka, indicating sparse vegetation in the lake basin and low lake level of Daihai Lake. To check this finding in a wider region, we collect droughty related records from 10 (paleo)lake basins in the North China and southern Mongolian Plateau, and find that most of former lake basins were covered by eolian dune or sand. It was a period of very harsh environment from 74 to ~50 ka for human survival in the wide region, which we thus name as the “Great Gobi-Desert” (GGD) period. Interestingly, the GGD period is simultaneous with very few paleolithic sites in the region comparing before and after, and also the conversion from archaic humans to modern humans. We hypothesize that the harsh environment of the GGD period, may extremely threatened the survival of simultaneous archaic humans, forcing them to move south or shrink to suitable refugia (e.g., Baishiya Cave of the Ganjia basin), leaving a sparsely populated wide region for the upcoming modern humans. After GGD period, environment started to ameliorate gradually, which might have contributed importantly in the flourishing development of modern humans.

Hominin paleoenvironment in East Asia: The Middle Paleolithic Xuchang-Lingjing (China) mammalian evidence

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The Chinese open-air site Xuchang-Lingjing (Henan) is located near the border between the Palearctic and the Oriental biozone in a lowland depression at the southern edge of the North China Plain. The site yielded a Middle Palaeolithic assemblage that includes the two fragmented, incomplete human (possibly Denisovan) skulls (Xuchang 1 and Xuchang 2), more than 15,000 artefacts and more than 40,000 mammalian remains representing at least 20 taxa. The composition of the faunal assemblage is biased by hominin hunting activities; it is, however, diverse and "natural" enough to be used as a proxy to reconstruct the paleoenvironmental condition during the human occupation of the site. The Palearctic faunal assemblage indicates a grassland-dominated palaeoecological environment, with a mosaic of scattered forest and mixed forest vegetation as well as along rivers and/or lakes the occurrence of swampy areas and with bushes. The OSL-dates and the assumed correlation with the last interglacial (MIS 5) palaeosol strongly suggest that we are dealing with an interglacial fauna. However, the fact that the Lingjing assemblage represents the southernmost Palearctic fauna questions the assumption that the Lingjing Middle Palaeolithic finds date from an interglacial period. A late Middle Pleistocene (MIS 6) or Late Pleistocene glacial or stadial phase (MIS 4) seems more likely.

Denisovans from Baishiya Karst Cave on the Tibetan Plateau

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In East Asia, mysterious Denisovans so far are only found in Baishiya Karst Cave (BKC) on the Tibetan Plateau. A human mandible found in the 1980's in BKC is confirmed to be from a Denisovan at least 160-thousand-years-old based on paleoproteomic analysis and U-series dating of carbonate crust outside of the fossil, providing the first Denisovan fossil evidence outside of Denisova Cave and the earliest human occupation evidence on the Tibetan Plateau. Subsequent archaeological excavation in BKC reveals that prehistoric human occupied the cave for a long time from the late Middle Pleistocene to the Late Pleistocene. Comprehensive studies of stratigraphy, chronology, archaeology and mitochondrial DNA extracted from the sediments in BKC suggest that Denisovans occupied the cave ~100 thousand and ~60 thousand years ago (ka) and possibly as recently as ~45 ka. Analysis of the rich lithic and faunal remains collected during the excavation shows that simple core and flake technology was mainly used for lithic production and various wild animals, including rhinos (probably wooly rhinos) and hyena, were hunted. Paleoenvironment studies in the site and Ganjia Basin where BKC is located indicate that Denisovans had experienced large environment fluctuations in this high-altitude region. The longterm and intensive occupation of BKC by Denisovans suggests that they may have adapted to life at high altitudes and may have contributed such adaptations to modern humans on the Tibetan Plateau.

Investigations of Middle Palaeolithic Levallois cores from Guanyindong cave in Southwest China

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The Levallois strategy at Guanyindong cave site dated 170-80 ka exhibits an early Levallois stone-tool technology application in East Asia. Since publication, the finding has caused widely attentions. Meanwhile the validity of Levallois stone-tool technology at Guanyindong also has been questioned. Detailed information and analysis given from the previous paper is limited, here we present analytical descriptions, technological illustrations, and quantitative analysis on prepared core found from Guanyindong. Our investigations further evidence the usage of Levallois concept at Guanyindong cave, indicating diversity knapping sequences during Late Middle Pleistocene in East Asia.

Evolution of vegetation and climate variability on the Tibetan Plateau over the past 1.74 Myr

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The Tibetan Plateau exerts a major influence on Asian climate, but its long-term environmental history remains largely unknown. Here, we present the first high-resolution record of vegetation and climate changes over the last 1.74 million years from a lake-sediment core from the Zoige Basin, eastern Tibetan Plateau. Results show three intervals with different orbital- and millennial-scale features superimposed on a stepwise long-term cooling trend. The interval 1.74-1.54 million years ago is characterized by an insolation-dominated mode with a strong ～20,000-year cyclicity and quasi-absent millennial-scale signal. The interval 1.54-0.62 million years ago represents a transitional insolation–ice mode marked by ~20,000-year and ~40,000-year cycles, with superimposed millennial-scale oscillations. The last 620,000 years are characterized by an ice-driven mode with 100,000-year cyclicity and less frequent millennial-scale variability. The most pronounced transition occurred 620,000 years ago, as glacial cycles intensified. These new findings reveal how the interaction of low-latitude insolation and high-latitude ice-volume forcing shaped the evolution of the Tibetan Plateau climate during the Quaternary.

Palaeoproteomics in the Middle and Late Pleistocene: prospects & challenges.

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The elucidation of the complex evolutionary relationships between Neanderthals, Denisovans, and modern humans has recently revealed a new picture of our own ancestral past. How preceding hominin populations fit into this framework is partly unknown. Such hominins were present across Africa and Eurasia, with large portions of the hominin fossil record outside the reach of ancient DNA research. Palaeoproteomic analysis of skeletal proteomes has recently emerged as a potential additional biomolecular approach across the Pleistocene that reaches much further back in time compared to ancient DNA. As a result, palaeoproteomics could provide molecular evidence on hominin evolutionary relationships on a global scale not reachable via other molecular methods. Based on several case studies and ongoing research of the ERC Project PROSPER, I will discuss and present recent developments in the field of palaeoproteomics that might make it possible to retrieve sufficient quantities of proteomic sequence information from Middle and Late Pleistocene hominin fossils, and how they might play a role in future discourse in human evolution studies.

Improving access to Pleistocene hominin skeletal proteomes

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Palaeoproteomic analyses of hominin skeletal materials have in recent years shown tremendous promise in a wide range of areas, such as species identification and studies of evolutionary relationships between taxa, beyond the general preservation limit of ancient DNA. However, ancient proteomes are often severely fragmented and damaged, and few endogenous proteins remain, posing significant challenges to palaeoproteomic analyses of Pleistocene material. Thorough method development and optimization are thereby essential parts of palaeoproteomic research, in order to ensure that the maximum amount of information is gained from each sample, while causing minimal damage to these rare and valuable materials. Here, we present results from testing the effect of digestion enzyme choice on the quantity and coverage of Pleistocene skeletal proteomes. First, we compare several different enzymes that are used for digesting proteomes prior to mass spectrometry, using faunal skeletal material from a range of time periods and preservation environments. Thereafter, we explore the effects of sequential digestion with different proteases, aiming to increase protein sequence coverage. The results from this study will allow researchers in the field of palaeoproteomics to optimize their laboratory protocols, in order to achieve robust and reliable results while minimizing the amount of destructive analyses that are performed.

Middle and Late Pleistocene hominin subsistence and ecology at Baishiya Karst Cave

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In 2010, geneticists reported a new archaic human group- “Denisovans”, by analyzing the mitochondrial and nuclear DNA sequences of a fragment of hominin phalanx from Denisova cave, in the Altai Mountains in Siberia. As a sister group of Neanderthals, Denisovans have attracted widespread attention from researchers in archaeology, paleoanthropology, genetics and other fields. Based on a decade of genomic research, geneticists reveal that Denisovans have contributed DNA to several present-day modern human populations, including East, South and Southeastern Asian populations, as well as aboriginal Americans and Oceanica populations, which implies that Denisovans might have been widely distributed in eastern Eurasia during Middle and Late Pleistocene. Moreover, palaeoanthropological data also support this hypothesis, suggesting Denisovans were capable of adapting to diverse environments, likely from high-latitude Siberia, to the high-altitude Tibetan Plateau, and low-latitude tropical regions of southeast Asia. However, due to limited archaeological evidence, we know little about Denisovan behaviours, including subsistence strategies, across the vast areas they likely occupied. Here, we describe the late Middle to Late Pleistocene faunal assemblage from Baishiya Karst Cave from in the north-eastern Tibetan Plateau (hereafter TP), where a Denisovan mandible and Denisovan sedimentary mtDNA was found, by integrating proteomic screening into traditional zooarchaeological analysis. The results indicate that the faunal assemblage includes a diverse range of animals, including locally extinct animals, species endemic to the Tibetan Plateau, and species common in the Palaearctic realm today. Frequent cut marks and percussion traces indicate that human activities are responsible for the fauna accumulation. Complete usage of acquired animal carcass resources might have helped Denisovans to survive through the last glacial-interglacial cycle on the high altitude Tibetan Plateau. Our results reveal Denisovan subsistence strategies, including behavioural adaptations that allowed archaic hominins to successfully occupy the high-altitude Tibetan Plateau environment.

Luminescence dating of the Sanggan River terraces in the Nihewan Basin, North China

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One of the most important regions for early human occupation in East Asia is the Nihewan Basin in North China, which is well-known for an abundance of archaeological sites with ages spanning the last 2 Ma. However, many Paleolithic sites found in the river terraces in the basin are either with no age data (e.g., Huoshigou site), or with controversial ages (e.g., Xibaimaying site). The lack of reliable ages for these sites affects our understanding for the development of the stone-tool technology in the Nihewan Basin. The aim of this research is to study the formation ages and the evolutionary history of the Sanggan River terraces (main river of the Nihewan Basin). Samples from different sedimentary facies of terrace deposits are systematically dated using post-infrared infrared stimulated luminescence techniques. With depositional age of each terrace, a reference geochronological framework is available for these discovered sites, which can be helpful for understanding the development of the stone-tool technology in the Nihewan Basin. The geomorphic evolutionary processes of the Sanggan River are also discussed which have significant implications for the relationship between human occupation and environmental change in Nihewan.

The Trans-Asian Mountain Corridor and Pleistocene Hominin Dispersals

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Archaeological, fossil and genetic data indicate a rich tapestry of interbreeding between ourselves, Neanderthals and Denisovans in Asia between ~200 and 45 ka, as well as perhaps other, as yet unidentified, hominins. Hominin habitats and ranges were likely highly dynamic, expanding and likely connecting repeatedly during periods with favourable ecologies, and contracting to refugia during (pan-)regional climatic downturns. This has been identified as an important driver of palaeodemography, population evolution, and material culture exchange in regions including Africa and central Asia. However, our understanding of dispersal routes that may have provided such connections, and of refugia in western and northern Asia remains limited. Key questions remain: By what *specific* routes, and at what *specific* times did opportunities exist for hominins to disperse across the vast tracts of south-west and central Asia, and interact? Where and when did refugia exist between such windows of opportunities?

We present a newly identified facilitator of hominin dispersals across northern and western Asia – the 'Trans-Asian Mountain Corridor' (TAMC), a single connected, spatially discrete route that allowed dispersal across Asia, stretching from the Levant and through northern Iran and Central Asia to the Altai. Our analyses indicate this belt of favourable environments exists today and repeatedly offered a suitable migration route, mostly during interglacials, but also some interstadials. The TAMC fractured into refugia during intervening periods, as suggested by both palaeoclimate models and regional environmental records. This repeated waxing and waning of ecological connections between disparate regions may have been a key driver of hominin dispersals, and of population and interspecific concentration into refugia, and thus opportunities to interact. Importantly, some periods when this nearly 5000km long corridor opened coincided spatially and temporally with the distribution of known archaeological markers of dispersal such as the Initial Upper Palaeolithic, and the general spatial pattern of archaeology across western Asia appears to closely relate to its broadly contemporaneous extent. We hypothesise that the TAMC may have functioned as an important pump for human dispersals and interaction, influencing their tempo and pattern. Its dynamics and internal refugia may well have created opportunities for hominin introgression in western Asia.

Chronology and artistic creation of Tibetan hand and foot prints

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Discovery of the middle Pleistocene hand- and footprints on Tibetan Plateau has generated great attention as the implication of the finding is so important for the research fields of archaeology, art history, human evolution and palaeo-environmental studies. The key points of the discovery are the date of the imprints were made and whether they can be called as "parietal art". In this report, we systematically provide the dating strategy and design in sampling, dating and stratigraphic analysis for the imprints and reveal the new dates of the imprints. Stratigraphic analysis demonstrates that there were multiples phases of travertine deposition in Quesang hot springs. The stratigraphic analysis, dating results from stratigraphic sequences and geochemical measurements indicate that the imprint-bearing travertine layer is in a "close system'. The dating sampling from the squeezed crests between fingers of a handprint shows that the imprints were made between 207~188 ka B.P. We also provided the dating results from ESR and ITL, which confirm the U-Th dates of the travertine and the reliability of the U-Th dating.

Extensive citations from current research on paleolithic-art validate that the term "Parietal art" is the most suitable term to describe the hand- and footprints discovered on Tibet. Based on the performance of modern artists, the definitions of 'art' from modern and ancient philosophers, estheticians and dictionaries, the evidence extracted from the pressing process, art elements and cognition of the imprints reflect that the imprints are an artistic creation of the hominine on Tibetan Plateau.

Thermoluminescence dating of Quesang Travertines from Tibetan plateau

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Travertine is one of the common terrestrial sediments associated with the intensive tectonic and geothermal activity. As a secondary calcite deposits, travertine documents abundant background information of the corresponding period during its formation, including paleoclimate variation, ecological environment, hydrogeological information, seismic activity, and even ancient human activities, etc.. Accurate chronological research of travertine is crucial and fundamental for the archaeological, paleoclimatic and paleoenvironmental applications. To date, plenty of dating approaches have been widely adopted, such as radiocarbon, uranium series, electron spin resonance (ESR) and thermoluminescence (TL). However, the scientific and effective dating method based on the cross-validation of travertine has been rarely discussed. In this research, we explore and evaluate the new thermal luminescence dating methods of travertine at Quesang hot spring in Tibetan Plateau, using the comprehensive methodology of thermoluminescence (TL) of isothoermal TL, MAAD and MAR. The results indicate the Quesang travertine dates to older than 400 ka. Comparison analysis revealed that TL dating method was promising in dating travertine, while ESR dating approach can be applied to travertine as well but with larger error. Other kinds of calcite deposition such as fossil, snail, loess calcite could be conducted in further research. This research provided solid technological reference for the travertine chronological research, as well as scientific basis for the prehistoric "human-land" relationship evolution research in high Tibetan Plateau.

The peopling of the hinterland of the Tibetan Plateau: A late MIS3 blade assemblage at Nwya Devu site

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Homo sapiens started venturing up in the high-altitude Tibetan Plateau by the late Marine Isotope Stage 3. Yet, it is still unclear why the late Pleistocene hunter-gatherers expanded into such a harsh environment, where they came from, and how the interactions were between the highlanders and lowlanders. To address some of these questions, we examine lithic assemblages from Nwya Devu, which is an open-air site in the hinterland of the Tibetan Plateau. We analyze the features that characterize the Nwya Devu assemblages, and the results show that it is a generic Upper Paleolithic blade technology. As the earliest blade site lacking antecedents within the highland, it points to a technological association with the blades at Shuidonggou site in North China and in the two regions of the Siberian Altai and North Mongolia in lowlands. Then, we apply a Least Cost Path analysis to model optimal routes from the possible origins of the blade technology to study how human populations would have migrated up to the high-elevation Plateau. We note that there are two possible scenarios to migrate up to the Tibetan Plateau from North Asia: the shorter path cutting through the Gobi Desert; bypassing the Gobi and moving through the margin of it. Shuidonggou site is an important stop connecting the two areas. Overall, the blade technology at Nwya Devu site might have been brought to the Plateau from the Steppe, at a time when early modern humans migrated into East Asia.

Ancient DNA and multimethod dating confirm the late arrival of anatomically modern humans in southern China

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The expansion of anatomically modern humans (AMHs)from Africa around ca. 65 to 45 ka led to the establishment of present-day non-African populations. Some paleoanthropologists have argued that fossil discoveries from Huanglong, Zhiren, Luna, and Fuyan caves in southern China indicate one or more prior dispersals, perhaps as early as ca. 120 ka. We investigated the age of the human remains from three of these localities and two additional early AMH sites (Yangjiapo and Sanyou caves, Hubei) by combining ancient DNA analysis with a multimethod geological dating strategy. Although U–Th dating of capping flowstones suggested they lie within the range ca. 168 to 70 ka, analyses of ancient DNA and direct AMS^{14}C dating on human teeth from Fuyan and Yangjiapo caves showed they derive from the Holocene. OSL dating of sediments and AMS^{14}C analysis of mammal teeth and charcoal also demonstrated major discrepancies from the flowstone ages; the difference between them being an order of magnitude or more at most of these localities. Our work highlights the surprisingly complex depositional history recorded at these subtropical caves which involved one or more episodes of erosion and redeposition or intrusion as recently as the late Holocene. In light of our findings, the first appearance datum for AMHs in southern China should probably lie within the timeframe set by molecular data of ca. 50 to 45 ka.

Lithic technology, cultural development, and human interaction: reevaluation of flake tool assemblages in North China during MIS 3

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North China is an essential region for understanding the evolution of hominins and their lithic technological behaviors, especially during the MIS 3 when anatomically modern humans and symbolic behavior emerged. Previous research in this region focused more on indicators of intrusive population such as large blade technology, but the vast areas were still largely occupied by producers of small-sized flake tools. This paper provides a new perspective on flake tool industry in North China to understand the lithic technology, cultural development of local inhabitants and their interaction with neighbors in the far north.

Systematic analysis of flake tool assemblages during MIS 3 North China indicates that local lithic technology in general inherited the “small-sized tool tradition” which was regionally prevalent throughout the Pleistocene, but differences in core reductional methods could be observed compared with earlier sites. On the other hand, MIS3 sites in North China also demonstrated variations in raw material selection and toolkits, which imply high regional diversity in behaviors within the same cultural tradition.

Meanwhile, some new cultural traits, including personal ornament, ochre, formal bone tool, grinding tool, and end-scraper, emerged in North China from ca. 41 ka cal BP gradually and sporadically, indicating there were limited but repeated cultural transmission and human interaction at the northern rimland between the blade and flake tool industries. Evaluation of probability density of radiocarbon dates indicates a near-simultaneous rise in North China and areas farther north since around 42ka, suggesting communication between blades and flake tools was possibly triggered by the population growth of both groups during the same period.

Keywords: MIS 3; Flake tool industry; New cultural traits; Interaction; Population growth

Archaeological occurrences of ostrich eggshell beads in late Pleistocene through early Holocene Mongolia and Northeast Asia

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Personal ornaments is considered to be the one of the marker of the *Homo sapiens* cultural suite along with volumetric uni- and bidirectional large blade production, Levallois technological elements, and specific tool types, well-known as Initial Upper Paleolithic. Ring-shaped beads are known from many Initial /Early Upper Paleolithic sites. This shape did not play a pivotal role in IUP artistic fashion in Europe and Siberia, but became a common form in Mongolia and, later, in North China, because the raw material used to fabricate these beads dictated its own terms: this type of bead was made of a specific raw material – ostrich eggshell (OES). The Asian ostrich inhabited the region now defined by modern Mongolia, North China, and southern Siberia from the middle Miocene to the early Holocene (ca. 13.65 ma to 8,900 cal BP). Here, we consider a broad spectrum of prehistoric human-ostrich interactions, reconstructed based on the chronology and regional distribution of ostrich eggshell (OES) beads in Central and Northeast Asia, focusing on Mongolia. This research provides additional paleontological, archaeological, and experimental data on ostrich eggshell bead production, yielding evidence that this type of personal ornamentation could have been manufactured by hand-drilling beginning in the Initial Upper Paleolithic. Ostrich eggshell bead production, along with the use of ochre as a pigment to color beads, is one of a suite of material cultural traits linking the Initial and Early Upper Paleolithic of Mongolia, southern Siberia, and the Transbaikal region. We tackled the complex problem of Asian ostrich eggshell taxonomy using pore measurements taken on OES fragments and beads. Bead-making technology was reconstructed through use-wear analysis and experimental replication. Microscopic examination identified various modes of potential prehistoric bead use ranging from personal ornamentation to clothing decoration. This is the first comprehensive analysis of the appearance and spatio-temporal distribution of OES beads associated with early *Homo sapiens* in the region, as well as the diachronic transmission of a bead-making tradition among later human populations up to the Mesolithic.

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Linking cultural and biological evolution dynamics during the Pleistocene. Insights from bone technologies in China

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The origin and development of bone technology in China are reviewed in the light of recent discoveries and compared to trends emerging from the European and African archaeological records. Three categories of osseous tools are targeted: (1) unmodified bone fragments bearing traces of use in technological activities; (2) bone fragments modified to a variable extent with techniques generally used in stone technologies; (3) osseous fragments entirely shaped with techniques fit for the manufacture of formal bone tools with a high degree of precision. Early evidence of bone technologies in China are sporadically found in contexts dated between 1.8–1.0 Ma and appears to have been introduced in the archaeological record by *Homo erectus* groups dispersing in the region. By the late MIS6–early MIS5, bone tools are well-integrated in the technological systems of Pleistocene populations and the rules guiding their use appear increasingly standardized. In addition, the first evidence for the use of osseous material in symbolic activities emerges in the archaeological record during this period. Finally, between 40–35 ka, new manufacturing techniques and products are introduced in Late Palaeolithic technological systems. It is first apparent in the manufacture of personal ornaments and followed by the production and diversification of formal bone tools. By that time, population dynamics seem to become materialized in different aspects of material culture. Despite regional specificities, the cultural trajectories identified for the evolution of bone technologies in China appear broadly similar to those observed in other regions of the Old World. We argue that prior to the emergence of formal bone tools, it remains difficult, given the current state of our knowledge, to establish links between cultural and biological evolution dynamics. We posit that this limitation may be overcome by investing further efforts in recognizing expedient osseous technologies and investigating how their role in past culturally adaptive systems evolved throughout the Pleistocene.

The complexity and diversity of hominin groups in South China during the Late Pleistocene: An archaeological perspective

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Paleolithic culture in South China has long been regarded as stable and without remarkable changes throughout the Pleistocene time, and this has been often used as evidence to support the regional continuity of human evolution in China, and East Asia as well. However, recent archaeological findings and research are changing this traditional perspective. Here, through analyses of several representative Paleolithic sites that were discovered in the different regions of South China, we aim to demonstrate the existence of complex lithic techno-complexes, along with other advanced behavioral characteristics. In general, the sites of Shanghu and Xiaojia which were found in the Jiangxi Province and were dated to ca. 35-12 ka, yield clearly miniaturized lithic assemblages primarily made on quartz. The site of Sandinggai was found in the Hunan Province and has been dated to ca. 96-13 ka, covering most period of Late Pleistocene. A co-existence of a Large Cutting Tool techno-complex and a small flake and flake tool production system occurred at the Sandinggai site, with the latter playing a more prominent role in the whole lithic assemblage. In addition, the sites of Tianhuadong and Longtan that were located in the Yunnan Province, have been selected for analysis. The age of these two sites has been dated to ca. 95-40 ka. Interestingly, a large quantity of Quina-like scrapers were identified from these two sites. These scrapers were mainly made on thick flake blanks, with scaled retouching scars distributed on either side or transversal edges of the tool. Overall, the analyses of sites from different regions of South China clearly demonstrate the diversified and complicated nature of lithic techno-complexes in the Late Pleistocene South China, which furthermore, provides important evidence for our understanding of the complex relationships among distinct hominin groups lived at that time period.

Climatic Fluctuation and Behavioral Diversity in Late Pleistocene Central China and Surrounding Areas

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Global environmental change and the fluctuation of East Asian Monsoon have played an important role in cultural development and human migration during Late Pleistocene. Located in the heartland of East Asia, Central China witnessed a gradual development of local flake tool industry during the warm and humid MIS3, together with the emergence of complex behaviors such as well-organized campsites and symbolic structures. With the arrival of harsh MIS2, bladelet-microblade technology appeared in this region for the first time, which might have been the result of a southward migration of Northeast Asian populations, and microblade technology continued to evolve till the end of Pleistocene.

Recently excavated materials in Chinese frontiers further exhibited several waves of population dispersal and cultural exchange during this time. The discovery of Tongtiandong Cave in Xinjiang, northwest China indicated an eastward expansion of Mousterian industry. In southwest China, archaic hominins carrying Acheulean artifacts have reached the southeast margin of the Tibetan Plateau since late Middle Pleistocene. At Qingtang Site in Guangdong, south China, the presence of small-sized flake tools at the onset of the LGM suggested that subtropical areas possibly have functioned as a refugee for populations used to live in the north, and the following prevalence of Sonvian Culture demonstrated connection with Southeast Asia.

These findings demonstrate that southward migration occurred majorly during glacial periods, while east-west communications became more convenient during warm intervals. Such movements generally involved various populations with very different technological traditions and adaptational strategies, and their behavioral diversity should not be simplified into a single “Out of Africa” event.

Environmental changes since the last interglacial recorded by loess deposits in the eastern Tibetan Plateau

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Aeolian loess deposits are widely distributed in arid and semi-arid regions of the world, and provide a valuable terrestrial sedimentary record containing rich paleoenvironmental evolution information. However, little is known about the loess distributed in the eastern Tibetan Plateau (TP), which is valuable paleoenvironmental archives for reconstructing the environmental history related to the Indian summer monsoon (ISM). In this study, we conducted optical stimulated luminescence (OSL) dating and detailed magnetism parameter analysis of the Ganzi loess sequence that developed since the Last Interglacial. Our results are as follows: (a) OSL dating can provide good age constrain for the Ganzi loess since the last interglacial. (b) The pedogenic processes dominated the magnetic enhancement, and magnetic parameters can be used to reconstruct precipitation history. (c) The reconstructed precipitation shows that rainfall in the eastern TP had varied dramatically, and the wettest periods over the last glacial cycle were the later interglacial and the Holocene. High frequency and amplitude variations changes occurred in the MIS3. We infer that the ISM and precipitation in the eastern TP were mainly driven by the combined effect of orbital changes, global ice volume, atmospheric CO_2 concentration, and internal climate forcing on the glacial-interglacial timescale.

Dietary niche reconstruction of Pliocene and Pleistocene Equidae from the Linxia Basin of northwestern China based on stable isotope analysis

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In this paper, stable isotope (δ^{13}C, δ^{18}O) analyses of five equid species from the Linxia Basin, northwestern China, were conducted to investigate dietary niche turnover during a critical Pliocene-Pleistocene phase in the evolution of Old World Equidae. In the Early Pliocene Shilidun fauna, *Proboscidipparion pater* is inferred to have mainly fed on C_3
grasses in open grasslands as indicated by their relatively high δ^{13}C values (−9.1± 0.4‰, five teeth, n=61), whereas *Cremohipparion licenti* and

Sivalhippus platyodus were possibly mixed feeders inhabiting woodlands and grasslands because of their comparatively low δ^{13}C values (−10.8± 0.6‰, seven teeth, n=36; −10.6± 0.6‰, nine teeth, n=35). Inhabiting the same environments, both *C. licenti* and *S. platyodus*
went extinct, possibly, because climatic changes led to a decline in woodlands resulting in greater competition. In the Early Pleistocene Longdan fauna, *Proboscidipparion sinense* had higher δ^{13}C values (−9.1± 0.5‰, four teeth, n=23) than coexisting *Equus eisenmannae* (−10.2± 0.5‰, eight teeth, n=57), implying that *P. sinense* had a stronger grazing preference compared to *E. eisenmannae*. Ecomorphological analyses (body size, tooth crown height, and enamel surface complexity) reveal that *P. pater* and *P. sinense* had dental characteristics consistent with a strong grazing preference. Therefore, *P. pater* might have been preadapted to open grasslands during the warm and humid Early Pliocene, which helped its descendent *P. sinense* persist into the Pleistocene. The results of this study reveal distinct dietary niches for these equids for the first time and shed light on some aspects of the evolutionary history of Equidae in East Asia.

Session 207: Not only z-corals: Quaternary reefs across the latitudinal and depth gradients

Not only carbonate frameworks by Mediterranean building organisms: the example of Sabellaria “living rocks”

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Relevant biogenic hard structures from the Mediterranean continental shelf include sabellarid, vermetid and coralligenous reefs resulting in complex three-dimensional formations. Either built up by polychaete tube-worms that grow side by side by agglutinating sands, by gastropod shells or intergrowing calcareous red algae, these biogenic structures modify the shape and increase the structural complexity of the seabed on which they develop. Their ecological importance is due to massive settlement and concretion on the bottom, leading to the formation of heterogeneous high porous/vacuolar skeletal frameworks which provide a variety of microhabitats for several organisms (algae, bryozoans, serpulids, foraminifers, sponges) and perform many functions (e.g. sheltered refuges, nursery areas), thus favouring biodiversity.

Among these reefs, vermetid and coralligenous concretions are persistent and solid calcified structures, potentially preservable through time and thus well-known in the fossil record, as they are entirely built by superimposed mineralized skeletons secreted by organisms themselves.

Differently, sabellarid bioconstructions relay on the relevant role of the biocement, an unmineralized glue that agglutinates detrital lithic elements. In fact, gregarious polychaetes of the genus *Sabellaria* (Annelida, Sabellariidae) build their rigid tubes in shallow shelf (mesolittoral to upper infralittoral) by means of secreted proteinaceous adhesives, capturing sand grains by surrounding waters. The still poorly known role and nature of this unmineralized cement, which is the only essential component allowing for the reef formation, is highlighted. The glue shows a bright fluorescence when excited with UV-light confirming its proteinaceous nature and allowing to detect its abundance and distribution in the tube. Glue is distributed in drops and strips and appears as a solid foam with numerous spherical bubbles. The major elements consistently observed in the biocement are C, N, Na, Mg, P, Cl, K and Ca.

Sabellarid bioconstructions can persist for many years but they are highly dynamic structures with cyclical phases of construction and destruction. Contrary to other carbonate Mediterranean bioconstructions and except for a few alleged examples, true sabellarid fossil reefs are still unknown, and due to their feeble fossilization potential, they turn out to be just a mass of sand.

Assessment of coral reef health at Lizard Island (Great Barrier Reef, Australia): benthic communities and foraminifera

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Lizard Island represents a classical site for investigating reef ecosystems within the Great Barrier Reef, Australia. In September 2022, we assessed the health status of the island's coral reefs using general observations of benthic communities (e.g., corals, calcareous coralline algae, bacterial mats), relative abundances of benthic foraminifera as well as seawater physicochemical parameters and nutrients. In particular, we applied three foraminiferal-based biotic indices that are widely used to assess coral reef ecosystem health.

The *Amphistegina* Bleaching Index (ABI) is indicative of the degree of photo-inhibitory stress, and with average seawater temperatures around 25°C in September 2022, it showed that this stress was chronic (in term of weeks) and mild or recent and moderate. The on-going investigation of the *FORAM*-Index*, Foraminifera* in Reef Assessment and Monitoring*, (FI) will be used to further evaluate the response of foraminifera and in general of the entire reef ecosystem to potential human impacts (e.g., resort) on the Island. The SEDCON Index, Sediment Constituents, (SI) together with sediment grain size* is indicative of the degree of bioerosion and, together with the FI, will reveal any potential deterioration of the reef environment.

Our current data suggest that, overall, the Lizard Island reefs are in good health and have not noticeably suffered from the temperature-induced bleaching that occurred in 2022. Ongoing research will allow us to further assess the health status of these reefs.

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Drowning caught in the act - a mesophotic reef in the Red Sea, Al Wajh, Saudi Arabia

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In the geological record, drowning of carbonate platforms is a common feature. It is usually recorded as an unconformity, or as deeper-water or pelagic sediments deposited on top of biogenic shallow-water carbonates in the stratigraphic succession. Drowned carbonate platforms and drowned reefs have been discussed as a paradox in carbonate sedimentology by Schlager (1981), because the accumulation rates of reef ecosystems in most cases exceed the rates of sea-level rise. However, rapid sea-level rises such as those during the last deglacial are well-known to cause drowning. Comparably high rates of sea-level rise are not observed today, so that modern analogues of drowning are rare.

Our study area is located south of the land-attached Al Wajh carbonate platform in the NE Red Sea. It has an elongated shape with 10 km to 4 km in diameter. During a collaborative research cruise between KAUST and JAMSTEC in 2022, the platform was mapped via multibeam, CTD profiles were measured, and sediment samples collected with a Van Veen grab sampler. The southern part is characterized by a thriving shallow water coral reef. The northern part in contrast is submerged in the mesophotic zone, reaching down to 80m water depth. The observed flora and fauna, characterized by abundant red algal crusts and encrusting foraminifera, indicate mesophotic conditions. We interpret this as a transient phenomenon in a rapidly deepening ecosystem where drowning is taking place on a block on the slope of the modern Red Sea, sliding down on plastic Miocene salt.

Mesophotic for-algal nodules: an unexpected bed from the Red Sea

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Biogenic carbonate nodules are benthic macroids built by one or more carbonate-producing organisms in approximately concentric layers. They are common constituents of modern mesophotic marine environments, where they form can form extensive beds on the seafloor (e.g. rhodolith beds), which represent an important component of the sea-environment resources, as they promote and support high biological diversity.

In the Red Sea, rhodoliths, both from shallow (Egypt, Saudi Arabia) and mesophotic (Sudan) environments, have been already reported in literature.

In the framework of the northern Saudi Arabian Red Sea (NEOM) giga-project for the exploration of the mesophotic and deep ecosystem of the Red Sea, the scientific surveys and the study of collected samples led to the discovery of free-living mesophotic Foraminiferal-Algal Nodules (FANs) along the coast of the NEOM region. Although an active foralgal factory was already describe from Sudan, where stable build-ups characterized the seafloor, FANs have been never described so far from the Red Sea. FANs aggregate into beds and form a distinct mesophotic benthic ecosystem occupying ~ 6 km^2 and covering ~ 10% of the continental shelf between 60 and 130 m of water depth.

Their coverage ranges between 25% and 100% of the seafloor, and their abundance ranges between 50 and 287 nodules *per* m^2. Radiometric dating informs that FANs can be more than two thousand years old and that they contribute up to 77 g m^2 $year^{-1}$ to the mesophotic benthic carbonate budget and accumulate at least 8937744.8 tons of CaCO3.

The temporal dynamic of these FANs is interesting. The FANs occur on flat or gently seafloor at the external limit of the continental shelf, which can end abruptly. We observe that FANs sometimes fall off the edge towards the deeper parts of the slope, where they eventually accumulate on finer sediment and presumably stop accreting. The nodules therefore represent a transport mechanism for carbonate formed on the shelf into the deep sea.

Our finding are similar to FANs record from Japan, although here there they do not form an extensive habitat as the one described from the Red Sea.

The physical basis for the occurrence of mesophotic reefs in the northern Mediterranean Sea (Adriatic coast)

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Some mesophotic bioconstructions and reefs has been recently discovered along the Apulian coast in the southern Adriatic Sea (northern Mediterranean). In this work, the first mesophotic coral reef reported in the Mediterranean area and some massive mesophotic oyster bioconstructions have been analysed with special reference to their physical constrains. A multidisciplinary (geo-ecological) and multiscale (seismic lines, sub-bottom profiler, multibeam, side-scan-sonar, video and meso-micro analysis on samples) approach has been adopted. A laterally continuous set of bioconstructions has been recognized at 35-75 m of water depth along a E-W oriented slope in the central sector of the Apulia shelf. They form a mesophotic system (Coral Reef Facies and Oyster Reef Facies) which gradually passes to a ubiquitous Coralligenous Facies in the shallower and flat portions of the shelf. The transition between Coral and Oyster Reef Facies is placed around 60 m of water depth, the well-known global community break of mesophotic coral reefs. The origin of the E-W oriented slope (transversal to the coastline) is tectonic and corresponds to the northern sector of the Monte Giove submarine relief. Here, a N-dipping transtensional fault, resulting from the reactivation of an inherited normal fault, strikes from the coastline to the eastern shelf sectors for about 25 km. The interaction between this E-W-striking fault and the S-directed circulation of cold and dense water currents induces the formation of upwelling processes which are responsible for the massive presence of mesophotic bioconstructions and reefs in this sector of the northern Mediterranean Sea.

The Holocene development of the Mediterranean algal reef Coralligenous

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Several types of biogenic reefs, build-ups and mounds are represented in the Quaternary of the Mediterranean, responding to the complex interplay of geological and environmental controls with a diverse set of habitats, architectures and components. The most important reef of the Mediterranean is the Coralligène (Coralligenous = C), including several types of calcareous algal-invertebrate frameworks growing in normal open marine conditions. The Mediterranean C is an Open Frame Reef, characterized by the variable association of calcareous red algae, bryozoans, annelids, bivalves, and corals. Although the living surface of C have been subject of numerous studies, the processes and the components controlling its development are still poorly known. The Italian project FISR "CRESCIBLUREEF" provided an extraordinary opportunity to explore the development of the Mediterranean C, from inception to present-day morphology and distribution, off the SE coasts of Sicily. Our analyses and the comparison with previous studies on the Ligurian C yielded some results that are relevant both for our understanding of the Quaternary dynamics of the Mediterranean shelf environments and for the present-day management of this unique habitat. Below the depth limit of distribution of the *Posidonia* meadows, the spatial extension of the C hybrid banks over the studied Sicilian shelf controls the hydrodynamics at the seafloor, the carbonate production at the shelf scale, and the biodiversity. The analyzed C are Holocene in age and their development generated a significant change in the seafloor geomorphology. The most part of the framework is invariably built by calcareous red algae, despite the variable occurrence of scleractinians and octocorals on the living surface. The rapid dissolution of the cnidarian remains after death could explain their negligible contribution to the framework, that is very porous, with primary cavities derived from the mode of growth, shape and structure of the skeletonised builders and dwellers. An important secondary porosity derives from bioerosion and other taphonomic processes involving both skeletonised and soft-bodied organisms. A contribution to the construction of the framework is provided also by autochthonous and detrital micrite, with an important role of organic mediation played by sponges for the mineralization of the autochthonous fraction.

Role of bryozoans and serpulids in the present-day Coralligenous off Marzamemi (Sicily)

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Coralligenous is a Mediterranean habitat typically developed in shelf settings and known to host a dramatic species richness owing to its structural heterogeneity. Consisting of a plethora of different facies, Coralligenous is characterized by the occurrence/dominance of different types of organisms.
However, accretion of such bioconstructions and their preservation in the fossil register relay on the occurrence of sessile skeletonized organisms, especially coralline algae that form a three-dimensional framework. A restricted number of invertebrates actively participate to construct these biogenic structures acting as subordinate builders, binders and dwellers with their skeletons cemented to each other. Molluscs, foraminifera and barnacles can occur but bryozoans and serpulids usually play a major role encrusting outer exposed surfaces as well as cavities and crevices resulting from the irregular algal convolutions.
The role of these two last groups was investigated in the frame of the FISR project CRESCIBLUREEF focusing on Mediterranean coralligenous bioconstructions developing offshore Marzamemi (Sicily, Ionian Sea) between ca. 30 and 100 metres.
Accounting for less than 5% at both the outer surface and internal sections, bryozoans and serpulids are subordinate in the bioconstructions, but highly diversified. About 140 and 40 species have been identified, respectively. Out of them, 75 bryozoans and 35 serpulids actively contribute to the concretion with different carbonate amounts, depending upon their abundances and the sizes of their colonies and specimens, respectively. Some bryozoan species acting as bafflers during life have either uncalcified or lightly calcified colonies that rapidly decay after death. However, many species developing branching colonies of jointed articles that are attached to the biogenic structure by organic rootlets can be at least partly preserved within crevices together with species (either bryozoans or serpulids) encrusting secondary soft substrata, mostly algae and sponges. Their remains partly fill cavities helping to strengthen the bioconstruction.

Temporal and spatial variability of Mediterranean cold-water coral mound development during the last 400 kyrs

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Scleractinian cold-water coral reefs are considered to be key hotspots of benthic biodiversity in the deep ocean. Due to their relevant ecological role and susceptibility to anthropogenic disturbances protection and conservation measures have been applied to these habitats, even though they are far from being completely understood. When coral reefs are under persistent suitable environmental conditions and have a sufficient sediment input, they can develop and form large geomorphic structures known as coral mounds. The latter are sensitive to changes in climate and capable of recording such variations in the chemical composition of the coral skeletons. Prior to this study, coral mound formation data in the Mediterranean was limited to the Alboran Sea and to the last 15 kyr, due to the lack of gravity cores encompassing longer periods of time. A wide range of techniques, including U-Th dating, computed tomography and geochemical analyses were applied to acquire a better understanding of the spatiotemporal distribution of Mediterranean cold-water coral reefs and the processes controlling their evolution into mounds during the last 400 kyr. More precisely, the present study aimed to explore which are the main environmental variables and paleoclimatic events that have controlled coral mound formation in the Cabliers Coral Mound Province and the newly discovered Tunisian Coral Mound Province. In regards to coral mound formation, this work has expanded the current knowledge outside the Alboran Sea and back to 400 ka BP. Almost opposite development patterns were observed between the Cabliers and Tunisian coral mound provinces, with the former mainly developing throughout deglaciations and temperate interstadial periods and the latter during glacial periods. Nonetheless, both provinces seem to depend on a high surface productivity and an appropriate depth of the interface between Atlantic and Levantine Intermediate Waters for the coral mounds to develop. Lastly, the oceanographic alterations caused in the Eastern Mediterranean Basin during Sapropel events also seem to have had detrimental effects for coral mound formation in the Western basin.

Session 208:
Achievements and new perspectives in Quaternary sciences from scientific drilling

Drilling Overdeepened Alpine Valleys (ICDP-DOVE): Quantifying the age, extent and environmental impact of Alpine glaciations

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The sedimentary infill of glacially overdeepened valleys and basins is an excellent but yet poorly investigated archive with regard to reconstructing the age, extent, and nature of past glaciations. The already available geological information and infrastructure make the Alps an ideal area to study overdeepened structures. The International Continental Scientific Drilling Program (ICDP) project DOVE investigates a series of drill cores from formerly glacially overdeepened troughs at several locations around the Alps. All sites will be investigated with regard to environmental dynamics during the Quaternary, with focus on the glaciation, vegetation, and landscape history. Geophysical methods will explore the geometry of overdeepened structures to better understand the process of overdeepening. Sedimentological analyses combined with downhole logging, analysis of biological remains, and geochronological methods will enable us to reconstruct the erosion and sedimentation history of the overdeepened troughs. This approach will yield data quantifying the extent and timing of Middle and Late Pleistocene glaciations of the Alps. In a first phase, two sites have been drilled in late 2021 into filled overdeepenings below the past lobe of the Rhine Glacier in Switzerland and Germany, and both recovered a trough filling composed of multiphase glacial sequences. These two sites are complemented by three legacy drill sites that previously recovered filled overdeepenings below the eastern Alpine Isar-Loisach, Salzach and Traun palaeoglacier areas (Germany and Austria). All analysis and interpretations of this DOVE Phase-1 will eventually lay the ground for an upcoming DOVE Phase-2 that will complete the panalpine approach. This follow-up phase will investigate overdeepenings and their connected forelands and foredeeps in the formerly ice-covered areas from the western and southern Alpine margins through drilling sites in France, Italy, and Slovenia.

New insights into Quaternary overdeepened structures from near-surface seismic reflections – results from the ICDP-project 'Drilling Overdeepened Alpine Valleys'

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The sedimentary infill of glacially overdeepened valleys is one of the best-preserved (but yet underexplored) direct archives of the extent of past glaciations in and around mountain ranges. The ICDP project "Drilling Overdeepened Alpine Valleys" Phase-1 investigates drill cores from glacially overdeepened structures at five complementing locations along the northern front of the Alps and their foreland. Two of the drill sites, Tannwald (D; ICDP site 5068_1) and Basadingen (CH; 5068_2), both in the catchment area of the former Rhine glacier, were intensively investigated by pre-site reflection seismic surveys. Despite an extensive seismic survey, another inner-alpine location, Lienz (A), will not be drilled.

The reflection seismic surveys comprise classical 2D P-wave and innovative multi-component surveys; for Tannwald, even 3D P- and S-wave data were acquired. As seismic sources, hydraulic and electrodynamic vibratory sources were deployed, which have been specially developed for investigations down to a depth of several 100 metres. The different examples clearly demonstrate the potential of the methods to reveal detailed information about the shape and physical properties of the valleys and their sedimentary fill. Even for the more than 600 m deep Lienz Basin, the data allows to distinguish the various deposits in fine detail, such as slumping, fan delta deposits, and a modified monocline on the basin flank. For Basadingen, we interpreted a rather complex basin structure that is confirmed by the first results of the research drilling. The combination of P-wave and multi-component data in the Tannwald Basin provides complementary information and, thus, allows imaging details of structures that cannot be seen from one dataset alone. The 2D seismic lines were interpreted in terms of seismic stratigraphy and contributed much to the final decisions about the drill sites. Especially the 3D surveys in the Tannwald Basin clearly show glacial tectonics, namely a hitherto never recognized cuspate-lobate folding of the glacial sediments, which was not evident in the 2D data.

The presentation will focus on the potential of near-surface reflection seismic surveys for the investigation of Quaternary structures, especially glacially-overdeepened structures. For each of the three locations, highlights of the interpretations will be discussed.

Reinvestigation of a 880-m-long Pleistocene drill core record from the Eastern Alps (Austria)

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The first phase of the pan-alpine ICDP project DOVE (Drilling Overdeepened Alpine Valleys) investigates five drill cores from overdeepened valleys along the northern side of the Alps and their foreland as their sedimentary infill provides an excellent archive of the timing and extent of past glaciations. One of the investigated sites (ICDP-5068-5) is located near Bad Aussee (Austria), in the central part of the Northern Calcareous Alps within the extent of the Pleistocene Traun Glacier. The drilling, which did not reach the bedrock, recovered an 880-m-long succession consisting of lacustrine and fluvial sediments (67 - 880 m) under a thick cover of subglacial till (0 - 67 m). It was first described by van Husen & Mayr in 2007, who proposed the formation of a more than 900 m deep lake caused by the dissolution of a large salt body by subglacial meltwater, which was subsequently filled by the sediments of a prograding delta. However, questions regarding the mechanisms and timing of the formation of this overdeepened structure remain.

Various sections of the drill core show high percentages of metamorphic rocks likely derived from the Austroalpine crystalline basement units. The present-day catchment of the river Traun, which drains the Bad Aussee basin, is largely composed of carbonate rocks. This suggests that the drainage network of this area of the Eastern Alps was very different during certain phases of the Pleistocene. We present results from sediment-petrographic and geochemical analyses which provide new insights into the depositional history and landscape evolution of the Bad Aussee basin. In addition, we present preliminary results from luminescence dating (based on a single grain dating approach for potassium-rich feldspar using post infrared, infrared stimulation @225°C (pIRIR225)), which will help establish a chronology of this unique sedimentary archive.

Uranium isotopes of authigenic minerals trace shifts in water sources to the Dead Sea during the Holocene

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The populated south Levant region at the desert fringe is drought-sensitive to the warming climate. Hydroclimate studies of past warm periods may help to picture future hydroclimatic scenarios. The Dead Sea lacustrine record, recovered by the Dead Sea Deep Drilling Project (DSDDP), provides a detailed history of alternating wet and dry intervals over the last ~220 ka. Multiple halite layers indicative of aridity were identified in the DSDDP core throughout the Holocene, with the thickest halite deposition occurring during the early Holocene (~11–10 ka). Here, we aim to investigate shifts in water sources to the Dead Sea during the relatively dry Holocene by analyzing $^{234}U/^{238}U$ activity ratios of authigenic minerals (halite and aragonite) in the core sediments. Our preliminary results show that the most significant fluctuation in the $^{234}U/^{238}U$ ratios occurred between ~11 and 10 ka, which coincides with the thick halite deposition. The $^{234}U/^{238}U$ ratios plummeted from typical values of ~1.4–1.5 that characterize the lake solution over long periods of the Quaternary to values of ~1.0. This change reflects a major shift of water sources from the north and west (Jordan River and Mediterranean-sourced rainfall, $^{234}U/^{238}U$: ~1.5–1.7) to the eastern and southern catchments and flash floods ($^{234}U/^{238}U$: ~1.0–1.2). Thus, the hydrological pattern of the early Holocene is quite different from the present day, in which the Jordan River is the main water contributor to the Dead Sea. At ~7.5 ka, the aragonite $^{234}U/^{238}U$ ratios increased to ~1.6, which is a typical signal of the Jordan River-western catchment sources. We suggest that the Dead Sea may have been stratified due to the large input of freshwater from the Jordan River, and the aragonites were precipitated from the upper freshwater layer and consequently recorded its $^{234}U/^{238}U$ ratios.

First evidence that about 1.07 Ma ago a one-kilometer asteroid striking west African forest triggered a major environmental crisis

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Around 1.07 Ma ago an asteroid stroke the pluvial forest of southern Ghana in Bosumtwi, generating a 10.5 km diameter crater and a distal ejecta of glass droplets in the form of tektites (the ivorites) and microtektites. A multi-proxy approach involving paleomagnetism, clay mineralogy, pollen, NPP and charcoal micro-particles was carried out on 40 samples of the IODP core 959 (Gulf of Guinea, N. Atlantic) spanning the period before and after the impact. We also studied 10 modern samples, taken during a recent field survey, along the Comoé and in the pluvial forest of Côte d'Ivoire. The microtektite layer was identified at 12.5 m depth in the core. This layer is found at the beginning of the Jaramillo subchron.

The palynological analyses of the IODP core 959 show that the entire rainforest (*Uapaca*, *Macaranga* Combretaceae, *palms)* but also the littoral mangroves (*Rhizophora*) and freshwater ecosystems (*Nymphaea*, *Lemna*, *Ludwigia*) were largely affected by the impact. Furthermore, megafires were ignited as suggested by the large amounts of microcharcoal and the spores of *Ustulina* and *Gelasinospora*. The large amount of unburned plant particles found in the tektites layer also proves that the forest was blown down by the impact blast, leading to an explosion of detritus feeders (*Coniochaeta*) and accelerated soil erosion (kaolinite, UAB7, *Glomus* peaks). The presence of spores of coprophilous fungi (*Sporormiella*, *Sordaria*) shows that herds of large herbivores were present in the ecosystem at the time of the impact. The sporo-pollinic and NPP assemblages of surface samples which include rainforest taxa, erosion (UAB7, *Glomus*), fire (*Gelasinospora*), vegetation decomposition (*Coniochaeta*) marker NPPs and large herbivores herds indicators (*Sordaria*, *Podospora*, *Delitschia*) confirm that biological and sedimentary material were transported by large rivers to the deep Gulf of Guinea where IODP 959 was retrieved.

This study was funded by ANR ET-MEGAFIRE project (2022-2026): "Tropical megafires triggered by tektite producing asteroidal impacts in the Quaternary".

Morphology of the Belize Barrier Reef as response to postglacial Atlantic sea-level changes (site-survey data for IODP preproposal “BBRdrill”)

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The mixed carbonate-siliciclastic barrier and atoll reef system offshore Belize is the largest modern tropical reef complex in the Atlantic Ocean. Based on a recent site survey for an IODP preproposal, which obtained highly resolved bathymetric and shallow seismic data from the area, an unprecedented morphological analysis of the reef tract was conducted to investigate the morphologic response of the reefal margin to sea-level changes. Several conspicuous features were identified that can potentially be correlated with sea-level rises or sea-level stillstands: Above some talus deposits forming a steeply dipping slope, the margin generally forms a vertical wall rising from ~100 to 45-65 m water depth, which is marked systematically by erosional notches at ~80 m, potentially indicating stillstands in sea-level rise. We hypothesize that older, postglacial and glacial reefs are stacked more or less vertically below the outermost ridge and the wall. At several locations, the top of the wall is marked by elongated ridges, up to 15 m high, behind which linear depressions occur.

These data were discussed during a Magellan workshop which lead to the definition of the drilling locations for IODP preproposal “BBRdrill” . Drill cores are expected to provide valuable comparisons with the existing eastern Caribbean (Barbados) and the Indo-Pacific sea-level records. In contrast to the Indo-Pacific, where post-glacial sedimentary successions of coral reefs including relative sea-level data were obtained from outcrops and coring (Vanuatu,Tahiti, Great Barrier Reef), there is only one such record in the Atlantic (Barbados, eastern Caribbean). The Barbados core data provided apparent differences to more recent, IODP-based data, e.g., the evidence of meltwater pulse (MWP) 1B, the timing and height of sea level during the last glacial maximum (LGM), the apparent lack of microbialites, as well as mismatches with Holocene sea-level curves. BBRdrill will aim towards i) reconstruction of the LGM and postglacial sea-level rise in the western Atlantic; ii) reconstruction of environmental parameters using corals, coralline algae, and cryptic microbialites; iii) elucidation of reef paleoecology in relation to postglacial sea-level rise and associated environmental changes; and iv) assessment of microbial life in a barrier-reef system.

Variability in the water column stratification in the Bay of Bengal during the last 1.45 myr

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The seasonally reversing monsoon winds and a large freshwater influx make the Bay of Bengal a hydrodynamically unique basin. The resulting stratification in the water column affects the physicochemical parameters and productivity. The reconstruction of past changes in the upper water column stratification will give insight into the control of monsoon on the water column structure. The scarcity of long-term records from the Bay of Bengal limits our understanding of this on an orbital scale. We have used a 1.16 myr (MIS 47- MIS 8) record of planktic foraminifera assemblages and the difference in the stable oxygen isotopic ratio ($\Delta\delta^{18}O$) between the mixed layer dwelling *Globigerinoides ruber* and thermocline dweller *Neogloboquadrina dutertrei* from the IODP Site U1446 to understand the change in water column stratification and its relationship with the monsoon through the mid-Pleistocene transition (MPT). We report a higher thermocline assemblage and low $\Delta\delta^{18}O$ during the warm interstadials and higher mixed layer assemblage and high $\Delta\delta^{18}O$ during the cold stadials. We infer a stronger stratification during the warm interstadials and comparatively weaker stratification during the cold stadials. The strengthened summer monsoon induced high direct rainfall, and riverine influx inhibited mixing in the upper layer and created a shallow thermocline during the interstadials. We also report a shallower thermocline during the post-MPT period because of the strengthened summer monsoon.

On the heterogeneity of Plio-Pleistocene African hydroclimate: Processes and patterns from North (ODP Site 659) and East (Baringo-Tugen Hills-Barsemoi Basin) Africa

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The Plio-Pleistocene (5-0 Ma) encompasses several key changes in the frequency, amplitude, and trends of global climate, including the intensification of Northern Hemisphere glaciation (iNHG) (~2.75 Ma) and 41-kyr cycles in temperature / ice volume. Late Pliocene proxy records also inform model simulations of a >400-ppm pCO_2 world. Changes in the trend and periodicity of African climate across the Plio-Pleistocene are particularly important given their potential influence on human evolution, and yet existing records are often short, low-resolution, and / or regionally biased. As a result, many triggers of African climate change have been hypothesized—local insolation forcing, high-latitude teleconnections, Indian Ocean surface temperatures—that are difficult to distinguish with existing data.

Here, we use high-resolution (3-4 kyr) *n*-alkane-specific leaf wax hydrogen isotope (δ^2H_{wax}) records from Ocean Drilling Program Site 659 (3.6-2.5 Ma) and central Kenya's Baringo Basin (3.3-2.6 Ma) to compare the evolution of East and Northwest African rainfall regimes across the Plio-Pleistocene boundary. At Site 659, δ^2H_{wax} values and *n*-alkane concentrations vary strongly on 23-kyr timescales, with no significant secular change. Summer insolation, which remains constant across iNHG, is likely the primary driver of Northwest African rainfall. δ^2H_{wax} values are ~10 ‰ more deuterium-depleted than the late Pleistocene, implying that drying occurred well after iNHG, perhaps coeval with increased dustiness around 2 Ma.

In contrast, Baringo δ^2H_{wax} values display prominent 41-kyr variance and are most spectrally coherent with the north-south insolation gradient. δ^2H_{wax} values decrease by 11.5‰ around 3.05 Ma, indicating the onset of *wetter* conditions. They and most other long (>200 kyr) East African records covary with the IO zonal surface temperature gradient and West Australian hydroclimate on extra-orbital timescales (>100 kyr), showing that Walker circulation regulates rainfall along the IO rim.

Unlike the last deglaciation, Plio-Pleistocene climate transitions may be regionally heterogeneous across northern and equatorial Africa, with pronounced environmental gradients caused by the differing sensitivity to regional versus remote forcing. This illustrates the need for additional geographically-diverse, high-resolution paleohydrological archives.

Continental Scientific Drilling for Quaternary Paleorecords: Program Capabilities and Future Directions

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The Continental Scientific Drilling (CSD) Facility at the University of Minnesota is funded by the US National Science Foundation to support any project worldwide requiring drilling or coring on land or in lakes. Facility staff, frequently collaborating with the International Continental Scientific Drilling Program (ICDP), engage with community scientists to develop and implement CSD projects and advance community goals. Obtaining high-quality core samples from modern or ancient sedimentary basins to understand Quaternary paleoclimate and paleoecology continues to be a major research motivation, as emphasized in long-range science plans produced by ICDP and by the US scientific community. Numerous scientific drilling projects in development or queued for operations include modern lakes, paleolakes, and other sedimentary basins in the Tibetan Plateau, the Brazilian Amazon, Colombia, Guatemala, the western United States, Chad, Tanzania, Kenya, and Botswana, among several other locations for projects focusing on timeframes prior to the Quaternary or on scientific disciplines related to active processes (geomicrobiology, hydrology, geothermal, fault zones, seismicity, etc). Since 2018, major changes in community infrastructure and resources have required a new approach that leverages commercial drilling contractors, community facilities, and distributed expertise to provide the needed capabilities to reach project goals. This presentation provides a perspective on the timelines and developments for the largest recent and upcoming CSD projects, on changes in relevant program and facility capabilities, and the pathway to drilling operations in the coming decade.

Poster - sessions 2, 35, 55, 60, 66, 89, 90, 98, 137, 186

The impact of fire and different forest management strategies on Sphagnum-dominated peatlands – a case study from northern Poland

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Sphagnum-dominated peatlands have been affected by various disturbance events throughout their history. In the past, these disturbances were mainly connected with naturally ignited fires or seasonal droughts. With increasing human pressure, the range of most disturbance events has increased. Currently, the most common ones are climate change, mechanical destruction such as peat extraction or peat cutting, drainage, and human-ignited fires. Over the years, the difference in environmental and forest management strategies impacted peatland ecology, making them more vulnerable to disturbances and burning. In this study, we aim to recognize how peatland ecology changed along with changing forest management strategies and how peatland ecology changed in response to disturbance events throughout its history. We studied a core from Stawek peatland in the Tuchola Pinewoods, a Scots pine (*Pinus sylvestris*) monoculture forest in northern Poland. The Stawek peatland is a small kettle hole mire, highly susceptible to the smallest of disturbance events, making it a perfect archive record for palaeoecological reconstructions. We use high-resolution multi-proxy palaeoecology to reconstruct the history of the peatland, including pollen, plant macrofossils, testate amoebae, and a wide range of charcoal analyses: micro- and microcharcoal counts, charcoal morphological types, and Raman spectroscopy. We also support reconstructing the latest disturbance events using dendrochronological analyses of pine. Our results show that the peatland experienced a critical transition in vegetation composition and hydrology when introducing forest management techniques. The surrounding mixed forest was turned into a pine monoculture. The main change was a reduction in fire activity in the Tuchola Pinewoods. This change led to a dominance of *Sphagnum* mosses and an increase in peat accumulation rates. We believe that the results of this study can be helpful for the improvement of conservation planning for peatlands located in forested areas and monoculture forests.

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Informing past fire regimes using microscopic charcoal preserved in deep-sea sediments

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Large uncertainties remain in understanding the evolution of fire activity under projected warming scenarios because fire is a complex process to integrate into global modelling. Empirical models used for projections lack potential changes in the interaction between climate, vegetation and fire. Process-based models of the coupled vegetation-fire system provide new tools to address this issue. Evaluating those models against benchmark datasets from charcoal sediment records, outside of the modern climate conditions range, is necessary. Long marine charcoal records capture regional-scale biomass burning over a large range of natural climate variability. However, the development of comprehensive data-model comparisons is limited by the lack of common physical units between data and model output: changes in ‘fire activity’ are not directly comparable to simulated fire regime characteristics (such as fire intensity or burnt areas). The ANR BRAISE intends to develop a calibration which, applied on paleofire records, should provide new datasets of regional fire regimes for key periods in the past.

Here, we present the analyses of abundance and morphology of microscopic charcoal preserved in surface sediment samples collected off Iberia and Africa. The spatial distribution patterns of microcharcoal parameters were compared with satellite derived fire regime characteristics on land (fire number, size, intensity and type of burnt vegetation). Results suggest the abundance and morphology of charcoal in marine sediments detect specific fire regimes, in particular fires of high intensity in mixed vegetation in Iberia and in graminoid-mixed ecosystems in Africa. These results are a springboard for converting marine charcoal records into past fire regime history.

Environmental change, fire events, and anthropogenic impact at Olzreuter Lake, SW Germany, over the past 15 kyrs reflected by a multi-proxy approach

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High-resolution multi-proxy analysis was applied to sediments from the Olzreuter Lake, SW Germany, including pollen, diatoms, chrysophytes, macro- and microcharcoal, total organic carbon, and X-ray fluorescence linked to archaeological evidence. The sequence provides detailed integrated records for the development of the lake habitat and the surrounding landscape during the interval from the Late Glacial to the Late Holocene. Vegetation reconstruction based on pollen covers a period from 14.7 to 1.6 calBP, and four zones were recognized. Open vegetation ruled the environment during the Late Glacial. In contrast, the Early Holocene was characterized by the spread of broadleaved trees like *Corylus, Quercus, Ulmus, and Tilia* (ca. 11.7 calBP), followed by the development of mixed oak forests (ca. 8.4 calBP) and finally, in Mid Holocene, from 6.3 calBP onwards dominated by beech forests. Macrocharcoal analysis detected local fire events; those from 16.6-12.9 calBP can be associated with climatic influences rather than anthropogenic activities in the area. However, between 12.9-8.2 calBP, the charcoal record in connection to archaeological evidence suggested increasing use of fire by the human populations. This pattern became pronounced later, especially between 11.7-8.2 and 4.2-1.8 calBP. Diatom analysis includes the section between 12.8-1.6 BP, with scarce diatom preservation between 12.7-7.0 calBP. As derived from diatom communities, lake level changes suggest that a rise in water levels occurred during the mid-to-late Holocene, as indicated by the ratio of benthic/planktonic diatoms. These rises overlapped with periods when the climate was more stable, while the lower water levels corresponded to the short intervals of glacier advances. Ecological characters inferred by diatom analysis showed that Olzreuter Lake generally had a mesotrophic status. At three-time levels - 12.8, 6.8, and 5.1 calBP - oligo-mesotrophic conditions settled in the lake. During the Mid-to-Late Holocene, enhanced sediment and nutrient input into the water body caused changes in the trophy status, which can be attributed to human agency. This study aims to reconstruct past environments and explore the interplay of anthropogenic influence and climatic control on the environment.

Fire variability in the southeastern France over the past 8500 years

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The French Mediterranean region is particularly impacted by fires today, with an increase of fire risk as a response of future projected climate change scenarios. However, fire models used for projections need to be evaluated against benchmark datasets from charcoal sediment records, outside of the modern climate conditions range. This study presents a new paleofire record covering the mid and late Holocene in southeastern France based on the analysis of microscopic charcoal preserved in a marine sediment core from the Gulf of Lions, located in the Rhone River prodelta. The relationships between fire, climate and vegetation cover were assessed through multivariate analyses. We found more fire episodes during dry conditions in the mid-Holocene when the vegetation was relatively closed (deciduous oaks, pines, evergreen shrubs, other deciduous trees). Conversely, we observed more fire episodes under wet conditions in the Late Holocene when the vegetation was more open (Artemisia, Olea, Ericaceae, other Herbaceous taxa, Poaceae). We show also that 12 fire episodes among 15 coincide with cold relapses detected in the Gulf of Lions. The presence of these cold events has been attributed to particular synoptic conditions such as the negative NAO mode, generating humid conditions on average but dry and cold wind anomalies, or the East Atlantic Pattern mode of variability leading to dry and cold winds in the Mediterranean region. Today, large fires in southeastern France occur either during negative NAO or during the Atlantic Ridge weather regime, the latter being connected to the East Atlantic Pattern mode of variability. Our results suggest that increases in fire in the southeastearn France during the Holocene were controlled by similar synoptic conditions than present-day leading to dry winds in this area.

Recent Environmental Changes in the Alpine Zone of the Rwenzori Mountains Unprecedented

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High-elevation tropical regions are believed to be some of the most sensitive environments to climate change. In tropical African mountains, the effects of climate change have already caused glaciers to significantly retreat in the past century, and recent droughts, fires, and floods suggest that warming is impacting a variety of ecosystem processes and services. However, the short duration of observational records limits our ability to test whether these changes result from shifts in precipitation, temperature, or human activities. The Rwenzori Mountains, located on the border between Uganda and the Democratic Republic of the Congo, is one such region where the impacts of climate change are apparent. To assess the driving mechanisms of these modern climatic and environmental changes, we reconstruct fire (macro-charcoal and PAHs), precipitation (dD_{wax}), vegetation ($d^{13}C_{wax}$), and temperature (brGDGTs) to reconstruct climate during the Holocene in the Rwenzori Mountains. We present the highest elevation records of climate and fire in Africa using sediment cores from two different lakes: Lake Africa (3895 m asl) and Lake Kopello (4017 m asl). We find that past fire frequency tracks changes in precipitation with the exception of a significant increase in fire at 2 ka at lower elevation sites in the Rwenzori. We attribute this increase to the rise of pastoralism in Africa. Additionally, we find evidence that fires did not occur in the high-elevation afroalpine zone during the Holocene; this contrasts with the observed fires at this elevation today and suggests that modern fires are not part of natural climate variability and may be human driven.

Teleconnections between Holocene fire regimes in Central Asia and the Neotropics driven by Paleo Monsoon dynamics

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Wildfires play an important role in the global carbon budget and emitted wildfire aerosols contribute to radiative forcing of climate. Nevertheless, the drivers for long-term biomass burning trends on continental to global scale are still debated. Rising fire severity in past decades combined with large uncertainties about long-term fire trends raise major concerns about future fire management strategies. The boreal forests in Central Asia and the Neotropics are important regions for global fire emissions with only few available sediment records. The scarcity of data prevents inferring large-scale regional fire trends without ambiguities. High-alpine ice archives such as Tsambagarav Mountain in the Mongolian Altai and Illimani in the Bolivian Andes can fill this gap. They preserve microfossil records of past environmental change over millennia from large source areas that can be directly compared to many other climate and environmental tracers in the same ice core – thus providing a multiproxy record of supraregional fire and ecosystem change.
We found striking and surprising similarities between the Central Asian and Neotropical ice core paleofire records with declining fire activity during the Late-Holocene suggesting teleconnections between regional fire activity possibly due to shared climate drivers in the Northern and Southern hemisphere. Well-documented records of South American summer monsoon activity over the Holocene show a consistent strengthening towards the Late Holocene. The related southwards shift of the Intertropical Convergence Zone (ITCZ) resulted in increased monsoonal precipitation that reduced flammability of evergreen vegetation. In contrast, Asian paleo records suggest gradually weakening monsoon activity towards the Late Holocene that resulted in regionally drier conditions. These climate trends induced retractions of boreal forests, thus limiting fuel availability and fire incidence. We conclude that the main driver of fire activity in these two regions was not temperature but rather monsoonal-driven moisture sources regions. Therefore, paleo precipitation information and its influence on past vegetation conditions are crucial for global fire models. Siuch data will help to better assess the causes of regional paleo fire activity changes.

Mid- and late Holocene fire history in Central Siberia: effects of climate changes and human impact

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Recent climate change in Siberia is increasing the probability of dangerous forest fires. The development of effective measures to mitigate and prevent fires is impossible without an understanding of long-term fire dynamics. We present the new multi-site palaeo-fire reconstruction based on macroscopic charcoal data from 16 peat and lake sediment cores located in different landscapes across the permafrost area of Central Siberia. The studied sites are situated in three model areas: the Putorana Plateau, the middle part of the Central Siberian Plateau (Lower Tungiska River basin, near the settlement of Tura) and the marginal part of West Siberian Lowlands (Yenisei River basin, near the town of Igarka). Charcoal records cover the last 7000 years. We used the Paleofire R package version 1.2.4 as the standardization technique of the obtained data to compare the local fire reconstructions from the study area. The composite cureve of biomass burning was compated with pollen and plant macrofossil data, reconstruction of total forest covarage by best modern analogue technique and paleotemperature reconstructions. The obtained results show similar temporal patterns of charcoal accumulation rates in the cores under study, and near synchronous changes in fire regimes. The paleo-fire record revealed moderate biomass burning between 7.0 and 5.9 and between 3.4 and 2.6 ka BP. The periods of lowest fire activity occurred in 5.9-4.2 and 2.6-1.5 ka BP, that coincided with regional climate cooling and moistening, and reduction of forest vegetation in the study regions. Charcoal accumulation rates increased to the mean values during the interval from 1.5 to 0.8 ka BP and appears to be partly synchronous with climate warming during the Medieval Climate Anomaly. Since 0.8 ka BP charcoal influx raised and exceed the main value until the present time. With exception of charcoal records from the Putorana Plateau the decrease of fire frequency during the Little Ice Age revealed from tree-ring data from Central Siberia was not recorded by the charcoal data from peat cores. Fire frequency and charcoal accumulation increased abruptly during the last 150 years, obviously due to human impact.

Forest fire history in the central part of the East European plain in the Holocene

Mr. Dmitriy Kupriyanov [1]

1. -

The forest zone of the central part of the East European Plain is characterized by a complex combination of landscapes and a long history of human impact. The present study aimed to the reconstruction of the Holocene forest fire history for the central part of the East European plain (within the European part of Russian Federation). The study was carried out on the base of 17 sections of peat deposits located within the middle and southern taiga, the zone of mixed forests, in broadleaved forests and on the border of the forest zone and forest-steppe in different landscape positions. The main method of analysis macrocharcoal (particle size >125 μm) concentration in the peat deposits. Data processing was carried out in the «tapas» software (Finsinger, Bonnici, 2022). In the «Paleofire» package (Blarquez et al., 2014) was modeled an integral curve describing the trends of burned biomass over the past 8500 cal. years. Palynological analysis and other analyses were performed for each section to reconstruct the interaction of forest fires with climatic conditions and anthropogenic impact.

The results of the study showed that there are three stages in the history of forest fires in the center of the East European Plain. The first stage is from 6000-11700 cal yrs BP are characterized by frequent forest fires, which formed postpyrogenic forest communities with a predominance of *Punus* and *Betula* with a minimal proportion of broadleaved species. The maximum activity of forest fires is 7500-9000 cal yrs BP. Probably, the abundance of forest fires at this time is caused by climatic conditions. The second stage (2500-7000 cal yrs BP) is described by low activity of forest fires in colder and wetter conditions. At this time, broad-leaved or coniferous-broadleaved forests predominate (depending on the type of landscape). After 2500 cal yrs BP there has been an increase in the number of forest fires, probably caused by anthropogenic impact. This has led to a significant transformation of forests. The dating of 2500 cal yrs BP is conditional and varies according to the history of the development of different landscapes.

Holocene fire history: Methods, current knowledge, and potential for understanding past vegetation and climate dynamics in China

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Understanding the role of fire in the terrestrial biosphere and its consequences for ecosystem-climate dynamics is of key importance for projecting the climate changes in the future. The long-term interactions and feedbacks among fire, climate, and land use have been recorded in various sedimentary archives with which we can measure. Hence, numerous charcoal records have been accumulated produced as the by-products of pollen analysis have accumulated in China; however, several continuous or high-resolution charcoal records are required from different regions and ecosystems to synthesise the long-term trends in fire regimes and to examine the key drivers of fire activity. Herein, this paper reviews the state-of-the-art methodologies commonly used to study fire dynamics and present the examples of fire regimes by regions and biomes based on sedimentary charcoal records. Subsequently, specific concerns about the requirement of further studies on past fires at multi-spatial-temporal scales in China are addressed, which will help improving our understanding of the links among fire, ecosystems, and climate dynamics.

Determining the past fire regimes on the southeast coast of Australia

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Wildfires are an integral force shaping Australia's ecosystems, influenced by the stratification and composition of the vegetation, the climate, and human habitation. Although the presence and spread of past fires in Australia have been the subject of many studies, their temperature and intensity have been considerably less investigated to date.

This conference paper will present the main findings from the research on the changes in the fire regime (focusing on quantifying the temperature and intensity) during the Holocene at the Jervis Bay lagoon, on the south-east coast of Australia. The paper will firstly outline how a charcoal reference dataset was created for the main tree taxa from Jervis Bay (i.e., *Eucalyptus sp.*, *Casuarina*, *Banksia*, *Melaleuca*, and *Avicennia*). It will be described how the wood samples of these taxa were heated to between 200 °C and 700 °C in a muffle furnace and by open flame combustion, and the obtained charcoal samples analysed by Fourier Transform Infrared Spectroscopy (FTIR) to identify a range of spectral responses and their associated chemical structures. The data from FTIR were then correlated with the temperatures acquired from the heating of the tree taxa samples, and thus a reference dataset was created. The paper will then present the results of the FTIR analysis of the charcoal from the soil cores at Jervis Bay, representing the entire Holocene period, which were interpreted against the reference dataset, and in this way, the periods of higher and lower temperature of past fires through the Holocene were identified. The outcomes of this research can contribute to a better understanding and more effective management of present and future fires, especially considering the current unprecedented climate changes.

Reconstructing changes in paleofire regimes on the African continent using microcharcoal from marine sediments

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Fire is a ubiquitous component of nearly every terrestrial ecosystem and has been responsible for shaping the Earth system for millions of years. In the context of current and anticipated climate warming scenarios, the projected changes in temperature, precipitation and increase of anthropogenic activities are expected to increase fire occurrence and severity with consequences on the environment and human society. Despite the recent scientific advances, there are still large deficiencies in understanding the interaction between fire and other components of the Earth system and, thus, limitations in integrating this process in global models. Africa is a fire-prone continent, accounting for most of the worldwide burnt area and more than half of fire-carbon emissions. Still, few charcoal records from continental and marine sediments are available here.

Marine records provide information regarding long-term changes in biomass burning and can aid in understanding the relationships between climate change and fire activity. However, the signal represents only relative levels of biomass burning, and thus, the relationship between the fire regime on the continent and charcoal deposition in the ocean still needs to be completed. The present study uses an integrated approach to link the charcoal accumulation in marine surface sediment samples of modern ages from sites across the African coast and fire regimes on land. Our results show that charcoal concentration and morphometry changes are linked with the fire regime and the type of burnt vegetation on the adjacent continent. This modern-land ocean calibration is further applied on a long marine record MD96-2098, off Namibia, to reconstruct fire regimes over the past 23,000 years using fire proxy and modelled climate (temperature and precipitation) information. Such reconstructions can help to better understand the local to regional processes that govern the fire signal and contextualise current and past environmental changes.

Dust-borne soluble iron delivery to the Last Glacial Maximum oceans: Source inheritance versus atmospheric processing

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During the last 800,000 years, atmospheric CO_2 concentration during glacial periods was between 25 and 45% smaller than during interglacial periods. Roughly one fourth of this difference is estimated to be due to a dust-induced stronger biological pump, mostly in the iron-limited southern oceans and northern Pacific, during dustier glacials. How was dust-borne soluble iron delivered to the glacial oceans? In the present-day climate, dust-borne iron at emission is mostly insoluble and solubilized through proton- and organic ligand-promoted atmospheric processing. However, this may not have been the case during glacials. First, drier glacials may have implied less chemical weathering of continental dust sources, thereby raising source-inherited iron solubility. Second, present-day anthropogenic gas emissions acidify the atmosphere and enhance the solubility of dust-borne iron during atmospheric transport, an effect which was absent during glacials. We thus hypothesize that during glacials dust-borne soluble iron inputs to iron-limited oceans were more strongly controlled by source-inherited iron solubility, and less so by atmospheric processing, compared to the present. To test this hypothesis, we will perform a set of Last Glacial Maximum (LGM, 21 ka BP) and pre-industrial (1850 AD) simulations using the Community Earth System Model 2, with coupled atmospheric and land components and with an atmospheric iron processing module. Dust emission rates will be tuned against a compilation of LGM and present-day dust deposition flux observations, and sensitivity analyses will be performed on two parameters: source-inherited iron solubility of dust and the intensity of atmospheric processing. Results will be discussed in the session.

Sources of Danubian loess

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Sediment provenance can be a powerful tool in sediment system dynamics and transport pathways research. Through understanding sediment sources new insights into past environmental and climatic processes can be gained. This is particularly true for loess-palaeosol sequences which are one of the key archives of terrestrial environmental change. By coupling loess source information with chronological data we can quantify rates of process, such as dust transport and deposition processes, dust fluxes, and sediment generation mechanisms over the longer term, which is crucial when using loess as palaeoclimatic and palaeoenvironmental proxies.

Sources of sediment in loess sequences along the Middle and Lower Danube have been well studied with great improvements in our understanding gained through use of detrital zircons and their ages. However, some uncertainties, such as contributions from Saharan regions into Central Europe, still persist. Some geochemical palaeo studies suggested that Sahara made negligible contributions, and others produced inconclusive results. Conversely modern dust research shows relatively frequent contributions. This ambiguity limits our understanding of atmospheric conditions and transport patterns.

Here we build on our recent loess provenance work in the Danube corridor that focused on detrital zircon U-Pb ages and hafnium isotopes (Fenn et al. 2022), and expand it with loess Sr-Nd isotopes from loess deposits along the Danube (Croatia, Serbia, and Bulgaria). These are compared with corresponding potential source regions data with an emphasis on North Africa, to begin disentangling Saharan contributions to Danubian loess. We also explore bulk sample elemental composition and explore statistical ways that can bring these big datasets together to provide a clearer provenance picture. Finally, by combining the results with chronological information we explore any potential provenance changes over time.

Shutting down dust emission during the middle Holocene drought in the Sonoran Desert, Arizona, USA

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Long-term relationships between climate and dust emissions remain unclear, with two prevailing but opposite hypotheses for the effects of climate shifts: (1) increased dust emission due to increasing aridity imposing a vegetation change, or (2) decreased dust emission due to increasing aridity which imposes a less stormy climate and reduced sediment supply. Here we test these hypotheses by analyzing an 11-m-long core archiving Holocene dust trapped in Montezuma Well, a natural sinkhole in Arizona (southwestern United States), alongside current dust sources and transport pathways. Major elements indicate that Montezuma Well sediments originate from two end members: local carbonate bedrock and external siliceous dust. Core sediments are similar to the adjacent siliceous soils accumulated atop the bedrock, pointing to their eolian origin. Particle-size distributions reveal fine dust transported during winter from the northwestern Sonoran Desert and the Mojave Desert, and coarse dust transported during summer from the southwestern Sonoran Desert, similar to current climate systems and dust pathways. A survey of potential dust sources indicates that current summer and winter dust sources in the Sonoran Desert are under a supply-limited state. Dust fluxes were higher during wetter phases of the Holocene when winter sources dominated. During the middle Holocene drought, dust fluxes were minimal and dominated by summer sources until dust input ceased as drought conditions did not produce enough floods to refill sources with sediments. We propose that in the Sonoran Desert, dust emission is strongly connected with climate, increasing during humid intervals and enhanced by fluvial sediment replenishment at dust sources.

PADI: the Italian platform for optical properties of dust in ice cores

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For past climate conditions, ice cores offer an unique opportunity to study the optical properties of mineral dust aerosol and its role on climate evolution, as they preserve a pristine atmospheric input from the past. Aeolian dust preserved in deep polar ice cores has several properties providing key paleoclimate information such as: dust concentration, proxy for continental aridity, source intensity and hydrological cycle; dust grain-size, related to atmospheric transport; dust geochemical composition, indicative of dust provenance and environmental conditions at the sources and dust morphology (shape), that is a key parameter to assess the radiative effect.

For this reason an analytical platform dedicated to the optical characterization of dust in ice cores was created at the European Cold Laboratory Facilities of the University of Milano Bicocca. Currently, the system is made up of three instruments to retrieve the optical properties of such particles: an Abakus laser sensor, an instrument based on Single-Particle Extinction and Scattering (SPES) and a novel tool for Digital Holography. These instruments can provide information on the shape, size and absorption of dust particles. At the end of the analytical line a sampler collects discrete samples and additional instruments can be added to improve the measurement capability. This platform was developed to better meet the analytical needs requested by projects in the Italian Alps and in Polar regions (such as ADA270, EAIIST, OPTICE, Beyond Epica).

Study of eolian dust transport and its activity in the formation of the regional climate of the Caucasus (Georgia)

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Dust aerosols represent one of the main pollutants on the territory of Georgia and impact on regional climate. In this study, the WRF/Chemistry model with dust module was used to study dust particles transportations on the territory of Georgia from the Sahara and Sahel in Africa, Arabian and ar-Rub' al-Khali deserts located in the Middle East, Kyzyl-Kum, Karakul and Great Salty in the Central Asia. The results of calculations have shown the WRF model was able to well simulate dust aerosols transportation on the territory of Caucasus in conditions of a complex relief of the environment (verified with CALIPSO and MODIS satellite products and HYSPLIT model). In addition, we have executed sets of 30 years simulations (1985–2014) with and without dust effects by RegCM 4.7 model with 16.7 km resolution over the Caucasus domain and with 50 km resolution encompassing most of the Sahara, the Middle East, the Great Caucasus with adjacent regions. Results of calculations have shown that mineral dust aerosol influences on temperature and precipitations (magnitudes) spatial and temporally inhomogeneous distribution on the territory of Georgia. According to results of comparisons of the simulated dust aerosol optical depth seasonal distributions against to the observed ones gave a good agreement. Also dust radiative forcing inclusion has improved simulated summer time temperature, and seasonal distribution of simulated precipitation, but gives over estimation in annual total precipitation. Results of calculations have shown that dust aerosol is an inter-active player in the climate system of Georgia.

High resolution dust fluxes and palaeowind reconstructions from Southern Hemisphere and Southern Ocean terrestrial records of the last 20 kyrs: new approaches and potential pitfalls

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In recent decades, the circumpolar Southern Hemisphere Westerly winds (SWW) have strengthened and contracted closer to Antarctica. This process has been associated with rapidly warming temperatures on the Antarctic Peninsula, enhanced Agulhas ocean current leakage, increased basal melting of ice-shelves, reduced precipitation supply to the southern continents, and a reduction in the carbon-sink capacity of the Southern Ocean. Although the SWW play a crucial role in driving global climate change, their millennial-centennial scale variability remains poorly constrained, limiting our ability to predict the impact of future changes. Over the last 10 years, we have collected new palaeoenvironmental records from lakes and peatlands on several Sub-Antarctic islands within, and peripheral to, the core SWW belt. In this poster, we: 1) use geochemical analysis of the bulk minerogenic component in peatland records to reconstruct local and long-distance dust fluxes, and provide a direct proxy of past changes in wind conditions across the Southern Ocean; 2) compare peatland dust flux data with independent (biological) proxies from the Sub-Antarctic islands alongside other terrestrial (lake and ice-core) records and models of changing wind strength; 3) examine new approaches to, and the potential pitfalls of, palaeowind reconstruction, such as using calibrated X-ray fluorescence core scanning (XRF-CS) data to increase the resolution of dust flux reconstructions to centennial (possibly) decadal timescales, and Hg isotopes as precipitation and wind proxies.

Understanding the atmospheric variability of the last glacial-interglacial transition in the Southern Hemisphere through paleoclimatic studies of high-altitude loess-paleosol sections in Argentina

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Atmospheric aerosols can have a significant impact on the global climate system due to the changes in the solar energy balance and the thermal radiation they produce, and also by affecting the primary productivity of oceans associated with increased deposition of iron. The loess-paleosols sequences located in Argentina are the most extensive continental paleo-records of aeolian material in the Southern Hemisphere, recording the deposition of dust transported by two major zonal wind systems: the southern westerly winds and the subtropical jets. In order to increase the understanding of paleo-atmospheric circulation over the Southern Hemisphere during the late Pleistocene-early Holocene, we are planning to determine physical properties (grain-size distribution and magnetic susceptibility) of two loess-paleosols sequences located in elevated regions. These analyses will be followed by optically stimulated luminescence (OSL) dates and provenance studies through radiogenic isotopes. In this sense, we will increase the existing spatial coverage of high-resolution paleoclimatic studies of loess sequences in southern South America, by adding to our previous studies two fairly unexplored sections: one located in the mountainous regions of NW Argentina (2100 m a.s.l.) and another in the Plateau of the Pampean Ranges (1600 m a.s.l). We hypothesize that these loess-paleosols records located in elevated regions, record the deposition of dust transported exclusively by the high-altitude circulation of the subtropical jet streams and grain-size variations of the deposits will evidence changes in the wind intensity. Therefore, these new sections will provide valuable complementary information for the Pampean loess belt about past variability in wind belts' position/intensity. Also, these studies will improve our understanding of the influence of the dust sources located in the Puna-Altiplano Plateau, and the latitudinal movement of the subtropical jet stream circulation over the past climatic hemispheric variability. Ongoing results will be discussed in the conference session.

Simulation of Global Dust Cycle and its Climate Effects During the Last Glacial Maximum

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Dust in the atmosphere affects climate by directly absorbing and scattering solar radiation. In present days, most of the dust is emitted from dry regions over North Africa and Arabian Peninsula. It has been shown that it impacts on global mean surface temperature, African monsoon, the number of tropical cyclones over the Atlantic Ocean, ENSO variability and the strength of Atlantic meridional ocean circulation (AMOC). The Last Glacial Maximum (LGM) is the most recent glacial period with a cold and dry climate. Observations and simulations both show that the dust loading and dust deposition rate during this period are much higher than those during the interglacial period due to the enhanced wind, weakened hydrological cycle and expanded dust sources. In this study, we use the fully coupled global climate model CESM1.2.2 to simulate the climate impact of changes in both vegetation distribution and dust cycle. It is found that the cooling effect of the vegetation change during the LGM was partially compensated by the change in the dust cycle. Moreover, the distribution of dust particle size varied mainly due to the change in dust sources.

4800 years of human induced atmospheric input of heavy metals and mineral matter recorded in an alpine peatland in Tyrol, Austria

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The European Alps have been subject to permanent environmental change during the Holocene, driven either by climate change or the impacts of land use in the form of pastoralism, mining and forestry as well as the continuing expansion of roads, settlements and tourism. The Piller Moor peatland in the Central Alps in Austria is among the few well-preserved peatlands in the region with a high potential to record some of the above-mentioned developments.

Our study uses geochemical data, measured by portable XRF and ICP-MS in a peat core covering the last 4800 years BP, to reconstruct and quantify past atmospheric fluxes of mineral matter and heavy metals in high-resolution. Our results indicate several episodes of metallurgical activities, which were largely unknown so far. The two most striking signals are recorded around 4500 cal BP and 1450 cal BP, with 0.8 and 0.65 $mg*a^{-1}*m^{-2}$ respectively, before any mining operations are historically documented. Furthermore, mineral input over the time of peat accumulation very well reflects erosive land use, like deforestation and grazing, and thus appears to be linked to it almost exclusively. This is most obvious around 2400 cal. years BP with nearly 9 $g*a^{-1}*m^{-2}$ and later in the Middle Ages and modern period. Although climate does not seem to have been the main driver of the signals recorded in the Piller Moor, cold episodes have very likely interacted with both mining and land use. Our results illustrate the high impact of land use on mountain landscapes like the Central Alps by adding a new level of quantitative geochemistry-based detail to knowledge that is mainly based on pollen and archaeological studies.

Present-day and historical dust emission from East Asia associated with climate change and land-use management

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Identifying dust sources and investigating the causes of dust emission are crucial not only to understand the comprehensive picture of dust cycle, but also to interpret the preservation of dust (loess) as paleoclimatic records. This study first investigates the spatiotemporal pattern and recent trend of dust emission from China and Mongolia using remote sensing techniques. A relatively long satellite-based time series of dust activity from 2001 to 2020 has been obtained, and it reveals that the Tarim Basin, Gobi and Qaidam Basin Deserts are three major dust sources in East Asia. It also finds that dust activity in northern China has been substantially reduced, and this trend and its pronounced interannual variability can be linked with recent changes in both climatic conditions and land-use management. Secondly, sedimentary records from one typical semi-arid dune field in northern China were used to reconstruct historical dust emission. It is found that dust emission has diminished significantly around 300 years ago because of policy-driven vegetation rehabilitation and dune stabilization. However, changes in human land-use since about 200 years have resulted in dune reactivation, and a large amount of dust was released due to erosion of pre-existing soil surfaces. These results indicate that dust emissions both during the historical period and at present in northern China are strongly influenced by climate change and land-use management. It also implies that the combined effects of climate change and human interference should be considered when evaluating the future potential of dust emission from these regions.

Holocene and Last Glacial Maximum dust deposition rate: Updated global datasets and interpolated fields

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Mineral dust aerosols are a key component of the Earth system, as their dynamics are controlled by and affect climate through diverse mechanisms. To quantify the role of dust on climate variability at glacial-interglacial time scales, it is key to retrieve information on past dust activity as registered geologically in loess deposits, peat bogs, lake and marine sediments, and ice. The two main dust parameters that can be quantified from these archives include deposition rate and particle size distribution. Quantifying these parameters is essential for guiding Earth system simulations with prognostic dust.

Several compilations of these parameters exist spanning the last □30 thousand years before present (ka BP), the newest released seven years ago. During these last years, there has been significant progress in the global coverage of paleo-dust proxies. Here, we update these previous compilations of global paleo-dust deposition flux and grain size observations. Two improvements are introduced. First, given the expected high variability of dust deposition fluxes during the last deglaciation, this new compilation discriminates between pre-industrial Holocene (PIH, year 1850 AD-11.7 ka BP) and Last Glacial Maximum (LGM, 19.0-26.5 ka BP) observations, filtering out dust flux constraints corresponding to the last deglaciation. Second, we derive an explicit uncertainty of bulk and <10-μm paleo-dust deposition fluxes, specific to each site and time period. We do so by compiling metadata necessary to calculate deposition fluxes, and their measurement uncertainties. Based on these new datasets and Climate-Krigger, a recently released global kriging interpolation algorithm, we will produce global interpolated fields of LGM and PIH dust deposition rate, including uncertainty maps that consider both data density and measurement error.

We obtained more than 200 LGM and more than 350 PIH records of bulk and <10-micron dust deposition rate. During the session, we will discuss these new datasets and the resulting interpolation and uncertainty maps, and what new insights they provide on last glacial-interglacial dust activity compared to previous compilation efforts.

Insoluble dust from the Dye 3 ice core

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Greenland ice cores provide a vast array of information of climate over the past glacial and interglacial periods. The drilling of the Dye 3 ice core took place at the Southern part of the central Greenland ice sheet (65°11'N, 43°50'W) in 1979-1981. The southern location is characterized by high accumulation rates and it was only the second such deep ice core to be drilled at the time. The core was after retrieval analysed by state of the art methods in the 1980's and for dust analysis coulter counter was applied. The ice has since been in freezer storage both in the USA and in Denmark and other analysis have been conducted.

We analysed the Dye 3 ice core by means of continuous flow analysis (CFA) 40 years after its retrieval (CFA, Bigler 2011,Simonsen, 2018) at the Physics of Ice, Climate, and Earth (PICE) group at the University of Copenhagen. As part of the CFA the quantity and grain size distribution of insoluble particles were measured by means of an Abakus laser particle counter. The sections analysed i 2019 covers the depths of 1753–1820m and 1865–1918m and represents both Holocene, Younger Dryas and Glacial sections (GS 5 to 12). We compare the new high-resolution insoluble dust ABAKUS CFA records with the previous analysis done by coulter counter and thus evaluate the two datasets from different decades against each other. Further we discuss the changes in the dust size distributions over the different climatic periods represented in the ice core. We also evaluate even shorter term fluctuations in dust sizes and their sources –suggesting some volcanic influence.

Monitoring present-day Saharan dust above and below the ocean surface

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Mineral dust plays an important role in the ocean's carbon cycle through the input of nutrients and metals which potentially fertilise phytoplankton, and by ballasting organic matter from the surface ocean to the sea floor. However, time series and records of open-ocean dust deposition fluxes are sparse. Here, we present a series of Saharan dust collected between 2015 and 2021 by dust-collecting buoys that are monitoring dust in the equatorial North Atlantic Ocean, as well as by moored sediment traps at the buoys' positions at ~21°N/21°W and ~11°N/23°W directly below the major dust Saharan-dust plume offshore northwest Africa. We present dust-flux data as well as particle-size distribution data, and make a comparison of the dust collected from the atmosphere at the ocean surface with the dust settling through the ocean and intercepted by the submarine sediment traps. See: www.nioz.nl/dust

Elemental analysis and reconstruction of Late Holocene climatic and environmental changes on the NE Tibetan Plateau

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Alpine ecosystems are particularly sensitive to climatic and anthropogenic change. The Qinghai-Tibetan Plateau is located near several deserts and drylands and is under the influence of various wind systems including the Westerly Jet and the East Asian winter monsoon (EAWM), which may affect mineral dust supply to the Plateau. As such this region is an important study area of past changes in climate and earth surface processes, and hence the Asian dust cycle.

Sediment cores from lakes and wetlands on the NE Tibetan Plateau were collected to reconstruct climatic variability and landscape evolution during the Holocene. This project aims at reconstructing climatic/environmental changes and anthropogenic activities during the Holocene using sedimentary, biological and geochemical proxies from wetland archives. Dunes nearby the study sites were also sampled. Samples from the sediment cores and dune samples were analyzed for elemental inorganic geochemistry (major and trace elements) in order to determine the composition of the mineral matter of the wetlands and to infer potential environmental and climate changes.

A 3.0m core was collected at Xing Cuo wetland, and the base was dated to 13.0ka cal BP. The core displays several changes between lacustrine sediments and peat ca 4.0ka cal BP, when the wetland was fully established. The timing of the inception of peat accumulation is similar in the other sampled wetlands and suggests a climatic influence over autogenous processes. Preliminary results on rare earth elements suggests the mineral matter in the Xing Cuo wetland is a mixture of local sources such as the dunes surrounding the site, and the deserts of northeastern China. Based on the preliminary age from 4.0ka to 1.5ka cal BP, the REE flux is relatively high and then displays a gradual decrease from 1.5ka onward, suggesting a change either in local environmental conditions or a broader climatic change (potentially changes in WJ or EAWM intensity).

Late Holocene atmospheric particulate loads over the north-western Pacific Ocean: volcanism, dust and human perturbation.

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Atmospheric particulate transport over the North Pacific Ocean is known to be significant for regional biogeochemical processes and climate. Despite this, there has been little work tracing the changing sources and relative loads of particulate aerosols in this important region over the Holocene. The deserts of northern East Asia are the 2nd largest global dust source, while the eastern extent of East Asia forms part of the Pacific ring of fire, therefore tephra forms a significant, albeit episodic component of atmospheric particulate loads. In this study, we use peat mires from the Daisetsuzan Mountains in central Hokkaido, Japan, to reconstruct atmospheric particulate deposition over the mid to late Holocene. The rare earth element (REE) and eNd composition of sediments deposited in the mire are used to examine particulate origin and to unmix the relative contribution of different particulate sources during the past 4 kyr. During the majority of the record, mineral flux was relatively low and was dominated by dust sourced from mainland China. However, within the past one thousand years more significant changes were in the peat. This includes the deposition of two major tephras. Although short lived, these significant eruptions resulted in an increase in atmospheric particulate flux in the mire by approximately 25 times compared to background dust flux. Further changes are recorded in the very top sections of the peat mire where Chinese dust input increases, especially after 1980 CE. This change is well constrained by ^{210}Pb and fallout radionuclides ($^{239+240}Pu$) and reflects agricultural intensification in China. The onset of significant anthropogenic dust is accompanied by an increase in accumulation of 'industrial' metals, such as Pb and Cu in the studied peat mire. Collectively, this demonstrates the scale of human perturbation of atmospheric particulate, even within a region where the atmosphere is loaded with 'natural' particulate aerosol.

A New Assemblage of Proboscidean Fossils from Central India and Associated Stratigraphic and Taphonomic Observations

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Proboscidean fossils from India have been discovered and studied since the 19th century. While the Narmada basin of central India is highly fossiliferous, discoveries of abundant skeletal elements of proboscideans in minimally-disturbed contexts are rare, with the majority of the collections being isolated fragments recovered from surface contexts. Here, we present a new fossil assemblage from the fossil hominin site of Hathnora, which was found to contain multiple skeletal elements such as ribs, humerus, vertebrae, etc. of a proboscidean, possibly all belonging to a single individual. Some of these skeletal elements have been preserved in an intact form. The minimum tentative NISP of the assemblage is 39 and is likely to increase. The quality of preservation and the reasonably large number of fossil bones provides us with an excellent opportunity to perform multi-dimensional analysis. Preliminary taphonomic observations shed light on the post-depositional history of the skeleton to correlate it with the fossil hominin findspot nearby (though both are stratigraphically independent and spatially separate). This study adds another piece to the puzzle of the evolutionary history of Indian proboscideans.

Human response for postglacial sea-level change in Jomon prehistoric sites around Lake Ogawara, Northern Japan

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In the Japanese archipelago, geoarchaeological research provides useful insights into the relationship between Holocene sea-level change and human activities. This archipelago is in a far field from the ice sheets and characterized by sea-level maximum during the middle Holocene. We focus on the Lake Ogawara, located in Aomori Prefecture, northeastern Japan, which are characterized by many archaeological sites during the Jomon period, ca. 15,000 to 2,300 calBP, around the lake such as the Futatsumori Shell Midden, one of components of the World Heritage Site “Jomon Prehistoric Sites in Northern Japan”. We conducted coring survey around the lake and reconstructed Holocene environmental changes with help of molluscan and fossil diatom analyses.

During the early to middle Holocene, rapid sedimentation of sandy deposits occurred in the northeastern to eastern coasts. According to molluscan and diatom assemblages, it is inferred that subtidal to intertidal environments had been occurred throughout this period. Shell middens during this period, mainly in the eastern coast, are characterized by abundance of *Meretrix lusoria* which prefers a marine sandy bottom. It is suggested that sea-level rise resulted in stable sandy bottom environment and might promoted selective habitation.

After that, shell middens were distributed mainly in the western coasts. According to the sea-level change curve around the study area (Yokoyama *et al*., 2012), sea-level rise rate slowed down after 7,000 to 6,000 calBP. This probably resulted in decrease in water depth, which indicates that caused environmental changes in the shellfish. It is possible that this environmental change caused people to move their settlements.

Around 4,800 calBP, *Corbicula japonica*, prefers brackish water, replaced M. lusoria. Results in the southern coast and lake bottom (Yamada *et al*., 2010) suggests that water salinity decreased after ca. 5,000 to 4,000 calBP due to developments of sand bars. Sea-level falling after ca. 4,000 calBP likely triggered sand bars development. Decrease in water salinity probably caused shell assemblage changes, and additionally caused archaeological sites migration to the northern coast, near the bay mouth.

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Geoarchaeological investigations in the coastal archeological site of Nora (southern Sardinia, western Mediterranean Sea)

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Mediterranean coasts have represented great places for relations and exchanges among peoples, especially since the proto-historical periods. In the Mid to Late Holocene (e.g., last 8 millennia) the combined effects of the slowing of sea-level rise and the increase of sediment input caused by both climatic and anthropogenic factors triggered the development of large Mediterranean coastal plains. These plains, heavily colonized by civilizations of pre-historical and historical periods, represent a major archive to better elucidate the millennial man-environment interactions along the Mediterranean coastal landscapes.
Here we present a geoarchaeological investigation carried out at the archeological site of Nora, a major Punic-Roman town placed in southern Sardinia (western Mediterranean Sea). The multiproxy analysis involved meio-fauna (benthic foraminifers and ostracods) and palynological analysis performed on two new cores collected in the coastal lagoons surrounding the archeological site. Furthermore, we carried out a geomorphologic and petrographic study of a number of beachrocks (paleo-shorelines) found few meters below the present sea-level. The chronological frame, based on a new set of 16 radiocarbon dates, allowed to provide fresh insights into the coastal modification of the last 4.3 millennia BP. In particular, we performed a high-resolution reconstruction of the local relative sea-level changes, which did not exceed the 1.35 m in the last 3500 years, and we identified the palaeoenvironmental dynamics that affected the lagoon system. These data allowed reconstruct the shoreline evolution of the area during the main period of occupation of the archeological site (e.g., from the Nuragic to the late Roman periods). This has been compared with the high-resolution mapping of the archeological structures in order to reconstruct their relationship with the paleo-shoreline at the time of their functioning period. Furthermore, palynological data elucidated the millennial variability in the vegetation dynamics as well as the anthropic influence in the changes of vegetational cover during the different archeological periods.

Changes in coastline and human exploitation of marine resources in S of Iberia (province of Malaga, Spain) during the late Upper Pleistocene and Early Holocene (ca. 15 – 11 ka cal BP)

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On the coastal strip of the S of Iberia (South of Spain), in its central sector corresponding to the province of Malaga, there are numerous karstic cavities with important stratigraphic sequences of the late Upper Pleistocene and Lower Holocene that contain abundant remains of human occupations, dated between ca 15 – 11 ka cal BP. The techno-economic characteristics of its archaeological records indicate that they correspond to the Magdalenian and are characterized by a strong presence of remains of marine animals, both invertebrates (molluscs, crustaceans, barnacles, echinoderms), and vertebrates (fish, birds, marine mammals) that, in their vast majority were contributed, processed and abandoned by the human populations that occupied these caves. At that time, the coastline was in positions lower than the current level (maximum -120 m, minimum -50 m) and at a distance from the current line between 4.5 and 1 km. The main sites that provide a good archaeological record are the Cave of Nerja (Nerja), Victoria Cave (Rincón de la Victoria) and the complex of sites of La Araña (La Cala del Moral). In this work we will focus on the Magdalenian occupations of these sites, located in different environments, from cliffs and coves to sandy beaches, allowing to establish a relationship between their paleogeographic position and the variation in the use of marine resources. This analysis will allow to fix the variations of the coastline throughout the episodes of human occupation, allowing to trace a paleogeographical reconstruction of the coast of Malaga in the final moments of the final upper Pleistocene.

The paleoenvironmental reconstruction of the Sarandapotamos river valley (Amarynthos, Evia Island, Greece): studying long term human-environment interactions.

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The catchment basin of the Sarandopotamos river on the island of Evia (Greece) has been an environment of habitation and worship since the early Neolithic. During Classical Antiquity, it hosted several settlements, as well as a major sanctuary dedicated to Artemis Amayrisa, which was recently discovered by a Swiss-Greek team. This discovery aside, a significant research agenda is to understand if, and the extent to which, the human history of occupation and abandonment in this region is related to its environmental history. Thus, the aim of this project is to use a suite of paleoenvironmental reconstruction methods to recreate ancient landscapes, environments, and evolution in order to understand society-environment interactions.

A model of the sedimentary dynamics of the catchment is being carried out using LAPSUS software, and sedimentary cores are being obtained in order to understand the relationship between environmental and human-driven (e.g. land use) change in the catchment, the geomorphic response of the delta, and the history of human occupation. The relationship between the delta and eustatic and isostatic history also has to be understood, which emphasizes the complexity of the project.

A multi-disciplinary and multi-scale appraisal of environmental and human history will significantly contribute to a better understanding of human-environmental interactions. This poster will present preliminary modelling results that demonstrate the sensitivity of the land-marine interaction to sea-level rise and delta dynamics from the late Pleistocene through the Holocene to the present.

Impact of human activities on increasing siltation along the south-western coast of India since the inception of the Anthropocene

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The South-Western Coast of India (SWCI) between 12^o N 15^o latitudes is the zone of intense south-west monsoon rainfall and often blanketed by evergreen vegetation and forest along the adjoining Western Ghats escarpment. The coastal zone is a narrow strip of land that varies in width from <5 km in the north to around 70 km in the south. The coastal geomorphic features indicate evidence of both sub-mergence and emergence of the coast due to sea-level fluctuations. There are three medium size rivers (~2000 - 5000 km^2) and more than 10 small rivers (< 2000 km^2) draining the area. The coastal zone is densely populated and anthropocentrically clustered with industrial and urban regions. The coastal region is under the stress of deforestation, changes in the lan-duse pattern, urban and industrial expansion and pollution, in terms of the accumulation of excess of silt and often pollutants. Five sediment cores collected from the estuaries and coastal embayments indicate that the silt contents in the coastal sediments increased from 1 % to 60%. The textural analysis of sediment indicates that silt contents generally increase from core bottom to the top over a span of about 70 years on the basis Cs-137 isotope activity. This could be due to the decrease in the velocity of the river flow as a result of the construction of dams and barrages across the rivers, as well as new bridge construction for the expansion of the national highways and construction of many breakwaters. Though the increasing trend in the accumulation of the silt is quite common along the coast, however, at some estuaries and backwater regions, there are sub-surface lows of silt fraction, suggesting episodic increase of sand fraction due to intense rainfall. The common consequences of human impacts on the coastal zone are coastal erosion, reduction in the dissolved oxygen in the coastal water, problems to navigation, accumulation of hazardous contaminants in the fine grained sediments. Due to this, there has been a considerable decrease in the dissolved oxygen concentrations in the coastal water, decline in the benthic fauna population as well as their biodiversity.

Geoarchaeology, chronostratigraphy and human occupation of the cental sector of the Cantabrian coast (North Iberia) during the Late Upper Pleistocene and Lower Holocene: The prehistoric sites of the Sella River estuary (Ribadesella, Asturias, Spain)

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The archaeological researchs that have been carried out in the last decade in the Sella river valley (central sector of the Cantabrian coast, North Iberia), in general, and in its stuary, in particular, are making it possible to specify the occupations of the groups of hunter-gatherers-shellfish gatherers who lived in southwestern Europe during the Upper Pleistocene and Lower Holocene. Thus, the review of the stratigraphies and archaeological materials from ancient excavations and the performance of new research projects at the classic sites located at the West bank of the stuary of Sella River (Cova Rosa, El Cierro, Les Pedroses, La Lloseta and Tito Bustillo) have made it possible to obtain new radiocarbon dating that allows us to specify the chronostratigraphic position of the different sequences while achieving a better understanding of the geological processes involved in the formation of these karstic deposits. In addition, the results of these investigations have made it possible to carry out a paleogeographic reconstruction of the coastline throughout the period between OIS 3 and OIS 1.

The TESTEREP project: integrated land-sea research to investigate the evolution of a former peninsula along the Belgian coast as a case study for coastal management

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Over the past decades, geological, paleoecological, archaeological, and historical research has led to a general understanding of the Belgian coastal plain's evolution during the Holocene and how people interacted with this changing landscape. However, existing research has for the most part been fragmented and fails to connect findings across the land-sea boundary. Questions about the interaction between on- and offshore geomorphological changes and the human impact on the landscape remain unanswered both on short- and long-term scales. In the TESTEREP project, studying the last 5000 years of Belgian coastal evolution, we aim to address these shortcomings through novel interdisciplinary research across the land-sea border. Testerep was once a peninsula located in the middle part of the Belgian coast, separated from the mainland by a broad tidal gully incised during the Iron Age. This gully was embanked and dammed during the Middle Ages and silted up as a consequence. Today, the landward part of the former peninsula has become part of the polders and beach, while the seaward side was lost to the sea. To study the evolution of the Testerep landscape over the past 5000 years, existing data on its historic natural (e.g. palaeo-channels) and artificial (e.g. embankments) features will be supplemented with new on- and offshore data for the area, collected using geophysical surveys, coring, metal detecting, excavations and sampling for radiocarbon and OSL dating. All information will be integrated through GIS analyses to produce palaeo-geographical maps that will form the basis for geomorphological and hydrodynamic modelling. This new land-sea integrated research will ultimately result in a better understanding of the driving factors behind the landscape change, assessing the relative importance of natural changes and human interventions. The project also includes a significant outreach component, using innovative virtual landscape reconstructions to pass on its multidisciplinary knowledge to stakeholders from policy, industry and the general public. This way, the project aims to raise public awareness about coastal dynamics and current threats and to inspire sustainable coastal management strategies for the future.

Reconstructing past environments at Ambergris Caye Belize: Evidence for Holocene wetland development and historical storms using a multiproxy approach.

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Patterns of long-term environmental and climatic change within the Yucatan Peninsula are fragmentary, with previous research focusing on periods of droughts related to the classic Maya and being restricted to mainland sites. Coastal regions offer an alternative archive for constraining environmental change, due to their sensitivity to both anthropogenic and atmospheric pressures. To improve the spatial and temporal pattern of climate within the Yucatan Peninsula, we present the first coastal palaeoclimatic reconstruction on the island of Ambergris Caye, Belize. We employ both diatom and geochemical analyses, to infer historical storms and wetland development from a 3.5 m peat core covering the last 6000 years. We interpret three periods of alternating hydrological change dating at ~4079-2609 BC, ~2609 BC - 620 AD, and ~1620 AD – present. Determining the hydrology of the bog was complex, with sparse diatom counts and limited preservation throughout. Geochemistry provided alternative means to constrain the hydrological changes within the wetland. Periods of increased moisture were identifiable from the increasing concentration of bog wetness, and redox indicators (Br, Mn). We speculate a correlation between the position of the intertropical convergence zone and moisture content, with northward movement resulting in precipitation. In contrast, drier intervals (~2609 BC- 620 AD) are identifiable by the significant decline in geochemical concentrations and transport of Saharan dust. Peaks in marine (Ca), seawater (Cl) and high energy (V) indicators imply six occurrences of marine inundation dating to approximately 2439 BC, 1591, 1769, 1874, 1930, and 1961 AD, however, there is no clear stratigraphic evidence present. Of the proposed tropical storms, two correspond with the historical records of hurricane Hattie (1961) and the unnamed 1874 event, resulting in four undocumented storms hitting the coast of Ambergris Caye, throughout the modern and palaeo record.

Late Holocene environmental dynamic of the Umm al-Quwain (UAE) lagoon and its implication for the quest for the ancient harbour of Omana

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Along the coastline of the Umm al-Quwain lagoon (United Arab Emirates), the Late Pre-Islamic (LPI; 3rd century BC – 3rd century AD) archaeological site of Ed-Dur (4 km inland from the extant coastline) is believed to be the ancient capital of *Omana/Ommana* mentioned by Pliny the Elder and the anonymous writer of the *Periplus Maris Erythraei* in the 1st century AD. On the contrary, the position of the harbour of ancient *Omana/Ommana* is still a matter of debate because the geomorphological configuration of Umm al-Quwain lagoon hides archaeological evidence of its existence. Remote sensing and fieldwork along the lagoon revealed that the north-eastern shoreline of the island of Akab displays a rectangular feature, likely related to human modification. Therefore, the area was investigated through several trenches, preserving sedimentary evidence for the shift of the sedimentary environment with the progressive migration seaward of the mangrove followed by the formation of a sabkha then covered by sand dunes. This evidence suggests that the sea level was higher than today likely supporting the exploitation of the island as a harbour. Archaeological evidence collected during the archaeological survey of the Island by the writers, as well as by old excavations, confirms the occupation of the island during both the Late Pre-Islamic and the middle Islamic (14th-15th centuries AD) periods. Such human presence could lend further support to the interpretation of Akab island as the locus of an artificially excavated harbour, although its precise date remains unknown. The data collected so far allow the reconstruction of a trade route over the Arabian Peninsula and shed light on the correlation between the mainland and an associated lagoon harbour within the context of the landscape evolution linked to Holocene climate fluctuations and the relative sea-level changes along the lower Persian Gulf.

Fungi marine bioerosion in human bones recovered in the Atamaca Desert (Northern Chile)

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In 2013 a human burial was found 2 m below the surface in the littoral dunes of Calderilla Beach (Caldera, northern Chile) at approximately 5.8 m above sea level. The bones represent an almost complete skeleton of a young male between 16 to 20 years old and, although no funerary artifacts were found it is possible that the grave had been previously plundered. The intense wear of the molars is characteristic of individuals of the Archaic period that inhabited the coasts of the Atacama Desert between 10,000- and 2,400-years BP. The most significant feature of the bones is that they appear completely bioeroded by endolithic microborings often highlighted by the precipitation of iron oxides or filled with a thin dark material. Al least two morphotypes of traces have been identified. The most common is a complex network of (sub)parallel radiating and ramifying tunnels of up to 100 microns in diameter with a straight to sinuous pattern. They are partly unroofed, in intermittent contact with the substrate surface. The other morphotype show a characteristic tear-shaped segments that gradually widen from a thin filament. A central cavity presents a slightly larger dimension and depth of penetration and develops below an initial point of entry, from which several fine segments (< 20 microns) emerge.

The dimensions and morphology of the microborings strongly suggest a saprophytic fungal tracemaker. In addition, the sandy deposit that appear in the cranium cavities includes siliceous sponge spicules, echinoderm spines, ostracods and marine benthic foraminifera. The taphonomic evidence suggests that the traces were produced during an undetermined period of marine water subaqueous exposure under the ground in a sandy beach (water table). This stage took place prior to one or several episodes of relative sea-level drop, probably caused by the most recent and abrupt coseismic uplift of the coast. Future paleoanthropological and geoarcheological studies will give further insights about the human settlements of the southern Atacama Desert coasts during the Holocene and the consequences of large earthquakes and tsunamis on the prehistoric human societies.

Fennoscandian erratics as a raw material for Neolithic tool manufacturing at the Baltic Sea coast (Rzucewo site)

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The multicultural archaeological site in Rzucewo (southern Baltic Sea coast), is a testimony to the use of environmental resources and adaptation to its changes since at least the sixth millennium BC. The area of the Puck Lagoon, on which the site lies, is the result of a multi-stage development: processes occurring during the last ice-sheet decay, transformation of glacial relief in the terrestrial environment, and then the sea ingression and the creation of the lagoon-marine environment.

During archaeological surveys a significant number of stone objects made of Fennoscandian rocks and those from the bottom of the Baltic Sea were obtained there. In the analysed set (334 items), the most common are sandstone, followed by diabases, amphibolites and granitoids. Sorting of a raw material and use its specific types preferred for the production of a given type of tool is recognized. The places of its acquisition shifted with the changes in the configuration of the coast caused by the sea level rise.

The most numerous in the analysed set are axes and adzes (91 specimens). Very common are artifacts that are evidence of the production of stone tools, especially polishing slabs (66 specimens, usually only as their fragments), accompanied by 7 polishing boulders. High intensity of tool use was identified, including reuse of worn and damaged tools, simultaneously with the fairly common presence of semi-finished tools and tools without signs of use. This is confirmed by earlier reports that in Rzucewo there is not only a record of the production of stone tools, but also regular processing of other material, such as wood, in order to make dugouts canoes. The complex of intentionally prepared places for the Neolithic production of stone tools is a very rare archaeological find in the northern Poland, and unique in the area of the Baltic countries.

Pollen and Non-Pollen Palynomorphs to detect the anthropogenic impact in the Mar Piccolo (Taranto, Southern Italy) during the Late Holocene

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The Mar Piccolo area has been settled since the Bronze Age whereas the history of its more close center Taranto dates back to the 8th century BC when it was founded as a Greek colony (Taras). Pollen and Non-Pollen Palynomorphs from a core (S05B, 29.49 m thick)) retrieved in the Mar Piccolo basin allow to investigate the paleoenvironmental changes, including those associated to the progressive increase of the anthropogenic impact, during the Late Holocene. Palynological data provide indication on the crops (e.g., Cereals), land use (e.g., *Olea*), farming (e.g., *Sporormiella*-type) and human/domestic animals presence (e.g., *Trichuris* sp.). They are expressed as: i. percentage of single taxa (e.g., *Olea*, *Vitis*, Cereals), ii. anthropic indexes (e.g., Regional Pastoral Index; Anthropogenic Nitrophilous Herbs), iii. concentrations of NPPs having a clear anthropic origin (e.g., *Trichuris*, *Ascaris*). Starting from 10.74 m a concomitant presence of Cereals, *Trichuris* and *Ascaris* attests the presence of settlements in the Taranto area at least since the Bronze Age. The continuous increase in *Olea* and anthropic NPPs highlights an increase in human activities around the basin possibly during the Greek and Roman periods. A subsequently notably increase of agriculture and herding activities during the Middle Ages is attested by both the great abundance of *Olea* and high concentration in *Trichuris* and *Ascaris*. During this time, historical events as famine, wars, or barbaric invasions are in fact well expressed by the percentage changes of some key taxa (e.g., *Olea*). The regional anthropic impact during the historical time, is also evaluated and compared to that recorded in the closest areas (e.g., Lago Alimini Piccolo). Worthy of note is the finding of pollen grains such as *Daphne caucasica* and *Citrus medica* which provide relevant information on chronology and trade.

Spatio-temporal analysis of archaeological radiocarbon dates from Hispaniola, Puerto Rico, and Cuba: implications for island colonization patterns and impacts

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Island ecosystems are vital to the study of biodiversity, human impacts on the environment, and pathways of migration and colonization. An increased amount of work has focused on the patterns, timing, and causes of the peopling of the insular Caribbean, which shows – among other things – that humans arrived in the Greater Antilles around 6,000 cal BP. However, relatively little work has focused on within-island colonization patterns. In order to address this, we utilize a new archaeological radiocarbon database of the Caribbean and, using a GIS approach, undertake a spatio-temporal "Hot and Cold Spot" analysis of the C14 data to examine within-island settlement patterns for Hispaniola, Cuba, and Puerto Rico. This analysis involved a calibration of all C14 data, which was then analyzed in ArcGIS Pro using IDW interpolation at bins of 800 to 500 years to highlight clusters of dates, representing areas of settlement (i.e., "Hot Spots"), and the inverse (i.e., "Cold Spots").

For Hispaniola, the results show that at 2,500 cal BP, human activity was concentrated at the south-eastern part of the island, but by 800 cal BP settlement shifted to the center-north. In the case of Puerto Rico, at 2,000 cal BP, settlement was focused in the east, whereas by 800 cal BP it had shifted to west. Our findings, while preliminary, will help archaeologists better understand the processes and causes of human dispersal within these large and environmentally diverse islands. In addition, our work has implications for questions to do with mid-Holocene extinctions in the Caribbean, and how early peoples may have altered island ecosystems. Future work will therefore focus on comparing this data with paleontological and paleoecological datasets.

The discovery of rice phytoliths from the late Holocene coastal peat layer in the Haitan Island, Southeast China and its significance

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The Haitan island in Fujian province, located on the southeast coast of China, is an important junction for the spread of Austronesian-speaking populations, their cultures, and agricultural technology to Taiwan island, Island Southeast Asia, and the Pacific Islands. However, questions regarding the emergence of agriculture in the islands of Fujian remain unclear, which hampers the understanding of the routes and processes of the southward spread of agriculture. In this study, samples from the peat layer of Core CJA2021 (25°37′5.81″N,119°45′28.74″E, a.s.l = 15 m), which is located in the Changjiangao Bay of the Haitan island, were collected for the radiocarbon dating, phytolith and pollen analyses. The dating result shows that the peat layer was developed between 3249 and 3060 cal a BP. *Typha*, Cyperaceae, and reed were the main morphotypes of pollen or phytolith counted in the peat layers, indicating a wetland and swamp condition in the Changjiangao Bay. The identification of rice bulliform phytoliths and cereal-type pollens in the peat layer suggests the emergence of rice agriculture on the Haitan island approximately 3,000 years ago. Rice phytoliths found in the Haitan island are the earliest rice remains in the islands of Southeast China, except for Taiwan island and Penghu islands. This study provides a clue for the further survey of archaeobotanical research on island sites. In addition, it may offer a new perspective to research the spread of prehistoric agriculture and its environmental background on the coastal islands of Southeast China.

Geomorphology, settlements and infrastructures in the ancient lagoon of Venice (Italy)

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The natural dynamics of formation and transformation of lagoons depend on the balance between the development of barrier islands, fluvial and tidal sedimentary input to the lagoon basin, and local trends of relative sea level (RSL). The evolution of the lagoon of Venice, the largest in the Mediterranean, is paradigmatic in this sense, as it encompasses all these three forcing factors. Its formation started about 7 kyr ago, thanks to the development of extensive barrier islands fed by longshore currents. These latter have been receiving abundant sediments from the mouth of major Alpine rivers, such as the Po, Adige, Brenta and Piave rivers, that debouch in the northwestern sector of the Adriatic Sea, in a general trend of RSL rise driven by geological land subsidence. The ancient human population and exploitation of the lagoon of Venice took place in this dynamic geomorphological and environmental context. In order to fully understand the processes of formation and preservation of lagoon archaeological sites, and to try to define the territorial dynamics underlying their distribution and function, it is thus necessary to reconstruct the changing structure of the physical landscape. In our contribution, we outline the geomorphological and paleoenvironmental evolution of the lagoon over the last millennia, in terms of coastline modification, re-arrangement of the tidal network, RSL rise, migration of river mouths. We further discuss their geoarchaeological significance in relation to main known settlements and infrastructures dating to the Roman period, as well as to the preliminary results of ongoing investigations (coring, surface and underwater archaeological surveys, geophysical surveys) at specific sites.

AMS radiocarbon ages of the Karekare Marsh, Rarotonga Island, Cook Islands

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Rarotonga Island, situated in the southern Cook Islands, South Pacific Ocean, lies in the western part of Polynesia. The apparent interruption of deposition (hiatus) between 2.8 and 0.7 cal ka BP (about 130 cm depth) in a 4 m-long core from the Karekare Marsh (elevation 1.65 m; area 0.114 km2) on Rarotonga Island, was previously reported. On Mangaia Island, located about 200 km to the southeast, vegetation changes were also reported to have occurred about 2 cal ka BP, suggesting that humans may have arrived during this period. To determine the hiatus of 2.8 - 0.7 cal ka BP is widely spread in this marsh, which may be related to the arrival of humans and the reason of lacking archaeological sites, we collected the 1150 cm-long core “Karekare 19-2”. It consisted of peat from 0 to 17 cm, silt from 17 to 154 cm, peat with plant fragments from 154 to 584 cm, silt from 584 to 1076 cm, and sandy silt from 1076 to 1150 cm. We obtained AMS radiocarbon dates for 37 higher plant fragments from various horizons, of which 11 were rejected due to stratigraphic inconsistency. These are thought to have been contaminated in during core sampling. The lowest radiocarbon age is 6320 +/- 30 BP, suggesting that this core records paleoenvironmental information for the past 7000 years. The hiatus between 2.5 and 1.1 cal ka BP at about 100 cm depth in this core is also recognized. Therefore, there is a high probability that hiatus is widespread in this marsh.

Comparing online versus offline assimilation for paleo-reanalysis

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Much of our understanding of historical climate comes from reanalysis based on instrumental data, but their length limits their use in studying longer-term climate variations. Paleoclimate proxy records are long enough to monitor multidecadal variability, and model-based paleo-proxy reconstruction has recently emerged to serve this purpose. However, they are reconstructed using an offline data assimilating approach that linearly combines states from a large dynamical model database – an approach that may misrepresent nonlinear quantities. Here, we compare the offline and online data assimilation approach using the Norwegian Climate Prediction model (NorCPM), which is based on the Norwegian Earth System Model and the Ensemble Kalman Filter data assimilation method. We assimilate coral data to constrain the ocean component of this model. The proxy base model that formulates the ensemble of proxy from the model state is constructed from the instrumental NorCPM reanalysis to mitigate model bias. In the online assimilation, we use 30 members and assimilate proxy every month. For the offline approach, the static ensemble is composed of 300 snapshots sampled from a stable pre-industrial model simulation. The performance of offline and online data assimilation is compared for the period 1950-2010 and validated using instrumental data.

Landslide zones detection with Sentinel-1 radar images: case of instabilities induced by sismic sequance, August 2020 in Mila, Algeria.

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Mountainous regions are subject to lands instability in Algeria and throughout the world. Earthquakes of high to moderate magnitudes are often landslide triggers that aggravate damage and loss. The region of Mila (Algerian NE) suffered on August 2020 an sismic sequence (two earthquakes) of magnitudes Mw=4.9 and Mw=4.4 that triggered many instabilities of ground causing significant damage to dozens of buildings. In order to contribute to the mapping of the inventory of these induced shifts, we used Interferometric analysis by radar imaging (InSAR). Two images from ESA's Sentinel-1A satellite, taken before and after the sismic sequence, were used. The result is very interesting as it allowed us to identify six (6) areas of major landslides whose area varies from 0.58km2 to 6.89km2. This result shows, the interest of new technologies, particularly InSAR, in identifying landslide areas during strong and moderate seismic events or during periods of intense rainfall. On the other hand, it raises the issue of the geo-risks associated with earthquakes in mountainous regions that must be integrated into urban development and expansion plans.

Frontiers of computer vision and artificial intelligence for the monitoring of the coastal systems

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An assessment of dynamic parameters characterizing a coastal system needs a large amount of data, which can be acquired and processed through new machine learning and computer vision techniques. These techniques allowed to implement a video monitoring system to obtain large spatially and temporally datasets well-distributed along the coasts. On the other hand, the video records can compile a series of continuous frames where a lot of dynamic parameters can be detected, such as wave flow, wave height, sediment movements, etc. In this work, we showed an innovative system composed of a combined approach between geophysical surveys, Convolutional Neural Network (CNN), and Optical Flow techniques to assess some parameters connected to energetic and mass balance of the coastal system. The sandy coast of Torre Canne was studied through a combined approach involving field surveys and video monitoring. A topographic survey was performed through terrestrial laser scanner and GPS-RTK for the coastal stretch continuously monitored by a web cam system. Furthermore, some video records were obtained through action cameras to extract video frames with high frequency. Classification and segmentation techniques were implemented in a CNN to extract the low frequency parameters of the sea-state (such as tide phases and surges) and the coastal landforms imprinted in the video frames. The high frequency parameters (such as wave flow and sediment movements) were extracted through Optical Flow techniques applied on the video records of action cameras. Results obtained through CNN and Optical Flow provide the physical parameters of wave propagation and coastal landforms. The application of CNN and Optical Flow techniques could represent an improvement in the application of monitoring techniques in coastal environments, permitting to automatically collect a continuous record of data that are usually not densely distributed or available.

Reconstructing Late Quaternary sea-level changes in the Western Mediterranean: Preliminary results from Corsica and Sardinia islands.

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Late Quaternary interglacials are relevant to understand how our planet responds to moderate warming trends. Late Quaternary proxies highlight that important changes may have occurred in coastal areas under higher global temperatures, leading to the deposition of peculiar morphologies and deposits, and driving changes of faunal distribution patterns. Studying the geological imprints of past interglacials is a fundamental tool to frame modern changes, and to assess the severity of future coastal changes as temperatures continue to raise unabated. The Mediterranean coastal zone has preserved a high number of Late Quaternary deposits, which may be used as archives to study sea-level and coastal environmental changes throughout the Late Quaternary. A recent review article summarized the published literature on Marine Isotopic Stage 5 (~80 to 130 ka) sites in the Western Mediterranean. From this review, it appears clear that the two major islands in this region, Corsica and Sardinia, host a wide variety of Late Quaternary marine and coastal deposits. Both islands appear to be tectonically stable within the Mediterranean context, therefore such deposits might be considered as a good benchmark for MIS 5 sea level in the basin. One aspect emerging from the review is the lack of standardized description and precise elevation measurement of the Late Quaternary deposits in Sardinia and Corsica. This hinders, at least in part, the potential to use them for paleoenvironmental and sea level reconstructions. This presentation belongs to an INQUA fellowship applied by Sebastian Richiano for the study of several localities in both islands joined with the team led by Alessio Rovere at Ca' Foscari University of Venice during May-June 2023. We will develop the two most informative sites and analyse them first to present them to the INQUA conference in Rome.

A new approach for studying sea-level changes using molecular fossils

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Targeted analysis of organic matter in soils and sediments is useful for evaluating past environmental conditions, as specific compounds may be directly linked to organisms and hence to the conditions reflected by their environment. These molecular fossils are abundant, well-preserved in sediments and their degradation patterns are well-understood, thus variations in biomarker distributions, such as lipids and chlorophyll pigments, have become a powerful tool for understanding palaeoclimatic change. The present study uses molecular fossils to provide insights into the impact of transgressive events on primary producers inhabiting a coastal environment, providing a more detailed record of sea-level change. Used alongside palaeontological evidence, molecular fossils can aid in the interpretation of paleoenvironmental changes and fill gaps in interpretation especially where microfossils are poorly preserved or present in low amounts.

Analyses of molecular fossils through a transgressive sequence from a Holocene sediment core from a lake in Scotland showed excellent agreement with the lithological and ecological interpretation and provided further insights into the depth of the transgression; the same approach was successfully applied to Mid-Pleistocene sediment cores where the elevation of the transgressive events was refined due to the higher sensitivity of primary producers to environmental changes. Molecular fossils have been successfully used as an additional method for defining the salt production unit in ancient saltpans and therefore, as a tool for reconstructing past sea level. Importantly, the analysis of organic molecular fossils provided sensitive records of primary producer response to major environmental changes such as a transgression. The molecular fossils analysed can reveal not only shifts in the primary producer organisms inhabiting the site, but also those in the surrounding environment. Linking the pigment and lipid records enables a more accurate record of relative sea-level change and its impact on paleoclimate during the Quaternary.

Last Interglacial (MIS5e) and MIS 9e relative sea level from Baia di Infreschi (Marina di Camerota, Southern Italy)

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Mediterranean coasts preserve many sedimentary and geomorphological features commonly correlated to the Last Interglacial (LIG) marine highstand. These are found at different elevations according to variable tectonics and glacio and hydroisostatic adjustment. In many parts of the Mediterranean, sedimentary deposits have been correlated with other oscillations during the MIS5 and/or at older interglacial highstands. However, the dating of these deposits has been problematic and controversial. The Cilento coast (Southern Italy) preserves evidence of relative sea level (RSL) changes within archeological caves, which offer the opportunity to reconstruct the RSL using different dating approaches. In this contribution, we review previous data and we present a new suite of RSL measurements using different markers, supported by U/Th dating on phreatic speleothems as terrestrial limiting points, and for constraining the ages of marine markers (i.e. notches and *Lithophaga* holes). According to our reconstruction, which covers several km of the coast, it is possible to recognize an upper horizon of *Lithophaga* holes between ca. 10-11 m a.s.l., which can be correlated with MIS9e. A second group of markers can be correlated to the LIG. The evidence for the latter comprises a subset of markers at ca. 5-6 m and, 4-2 m a.s.l. which indicates RSL oscillations during the LIG. These markers are older than ca. 120 ka. A suite of speleothems dated to MIS7 and early MIS6 indicate that the MIS7 highstand RSL was consistently lower than ca. 2 m a.s.l.

Reconstructing the rate and magnitude of Last Interglacial sea-level change in the North Sea and its global implications

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Sea-level projections are poorly constrained beyond the 21st century because of limitations relating to data availability and understanding of the response of ice sheets to a warmer climate. Under future climate scenarios, the instability of the West Antarctic Ice Sheet and its potential contribution to global and regional sea levels is unresolved. Observations of past sea-level change provide limited scenarios to test climate models under a global climate at least 1.5°C warmer than present, yet during the Last Interglacial global mean temperatures were~1-2°C warmer and sea level was ~5-10 m higher than pre-industrial values. Therefore, the Last Interglacial provides a valuable palaeo-laboratory for studying the mechanisms of sea-level change forced by warmer global temperatures and, in turn, helping to resolve future uncertainties.

We present results of reconstructing changes in Last Interglacial sea-level in the North Sea. We collected a series of sediment cores from the seafloor of the North Sea and developed a novel approach to establish the timing and indicative meaning of transgressive contacts. By combining a suite of sedimentary information with biological and geochemical proxies and new ice sheet and GIA modelling we produce a series of sea-level index points, which reveal the rate of sea-level rise in the North Sea during the Last Interglacial. We show evidence of high rates, with multiple meters of sea-level change in a few millennia during the peak warm period of the Last Interglacial. Because sea-level rise in north-west Europe is particularly sensitive to the source of melting ice, we our work can help constrain the contribution of the Antarctic Ice Sheet to global sea-level rise during the Last Interglacial.

New Relative Sea-Level Reconstruction for MIS 5e Interglacial from US Gulf and Southeast Coasts

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The Last Interglacial (Marine isotope stage 5e ~125,000 BP) is an important analog for future sea-level rise as global temperatures increase due to anthropogenic climate change. The World Atlas of Last Interglacial Shorelines created by the WARMCOASTS project has provided a guide for collecting additional datapoints to share with the scientific community. To grow this dataset, we conducted field surveys in the Gulf Coast and Southeast Coast of the United States to precisely identify and measure elevations of MIS 5e sea-level indicators on a passive margin. The survey covers stratigraphically complex areas of coastal beach ridges and preserved paleoshorelines left by highstands, including those where previous data had not been associated with quantifiable measurement errors or an elevation datum. Using precise DGPS measurements, we referenced the interglacial sea-level indicators and their modern analogs to the relevant hydrographic datum. This survey's results will be combined with future surveys to construct a transect of passive margin sea-level indicators in the Western Atlantic over thousands of kilometers, which will serve as a useful evaluation tool for models of glacio-hydro-isostatic adjustment and dynamic topography.

The Pleistocene sea-level record of the Balzi Rossi archaeological area, Ventimiglia, Italy

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The caves complex of Balzi Rossi (Ventimiglia, adjacent to the Italian-French border) is recognized as an important site for the study of Palaeolithic settlements within the Mediterranean and Europe. As such, it has been subject to archaeological investigation for over a century but with little regard for the associated coastal and marine deposits. A primary objective of the SPHeritage Project (MUR grant: FIRS2019_0040, P.I.:M. Pappalardo) has been to precisely identify, describe, and geochronologically constrain the numerous palaeo-coastlines that have been documented there. Constraining the sea-level record within the region will help establish the contribution of vertical Earth movements to palaeo and predicted sea-level change.

Former archaeological excavations have removed a significant quantity, if not all, coastal/marine deposits previously described at the multiple sites within the Balzi Rossi complex. In many instances, the deposits are preserved only as fragmented remnants at museums and other repositories. Despite this apparent obstacle, we were able to reassess the 'ghost' stratigraphic sequences using museum and repository archives (including detailed excavation notes) and trace remnants remaining at Balzi Rossi; both of which also served as sources of sample material for geochronological and sedimentological analyses. High-resolution topographic surveys allowed us to constrain the 'ghost' stratigraphy to trace remnants on-site. Various methods of geochronological constraint (U-Th, luminescence, amino acid racemization, Sr-isotope, palaeomagnetism) were applied 'fit-for-purpose', i.e., to those sample types most appropriate for the method. For example, U-Th analysis of flowstones to determine minimum/maximum ages of sedimentary deposits.

We provide a robust reconstruction for the last interglacial highstand, with an uncorrected envelope from sea-level indicators between 7-13 m above present sea level. Older early and middle Pleistocene highstand remnants are more difficult to constrain due to a lack of preserved material; however, the record allows for an estimated rate of long-term uplift for the region.

A Novel Method to Reconstruct Sea Level from Coral Microatolls Using Digital Surface Models

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Coral microatolls are precise indicators of relative sea-level (RSL) change as their upward growth is controlled by lowest tides, hence their morphologies reflect RSL trends as the corals grew. Extraction of a vertical (radial) slab through the microatoll for x-radiography is ideal and can uncover details of RSL changes from year to year, but is not always permitted or feasible. Moreover, due to the short periods during which corals are exposed at lowest tides, data collection in the field must be completed within tight time constraints. This usually results in a limited set of observations. Additionally, if the microatoll morphology is misinterpreted in the field or if subtle features are missed, it may not be possible to rectify the issues later.

To overcome these challenges, we are developing and comparing various techniques to acquire high-resolution digital surface models (DSMs) as a novel tool to study and quantitatively document coral microatolls. These techniques include structure-from-motion multi-view stereo photogrammetry, terrestrial LiDAR scans, and the Apple iPhone's built-in LiDAR scanner. DSMs can store large amounts of spatial information, and thus allow for thorough quantitative analysis and, where necessary, objective reanalysis of microatoll morphology even after field work is completed. This DSM approach is inexpensive, quick, and non-invasive. Due to its non-invasive nature, cylindrical cores must still be obtained for geochronological constraints. However, this is more feasible than slabbing. We also introduce a coral microatoll growth simulator created with Blender, an open-source 3D creation suite, to predict coral growth under different RSL histories. We manually tune the simulated microatoll morphologies to those observed in the field, to better constrain RSL histories. We show that DSM-derived metrics are accurate and replicable when compared to measurements made with established field methods, and they allow for rapid collection of detailed observations of an entire population of microatolls.

Sea-level changes in the Last Interglacial. How high, how fast?

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The Last Interglacial (LIG, Marine Isotopic Stage 5e, 125 ka) is a process analogue for a future warmer climate. Thousands of coastal relic landforms and deposits dating back to this period are studied today to obtain insights on two pressing questions: what was the peak LIG sea level? Was the LIG characterized by rapid sea-level changes triggered by sudden ice sheet collapses? While the answers to these questions remain to some degree uncertain, the data compiled within a new standardized database of LIG sea-level proxies, the World Atlas of Last Interglacial Shorelines, may help refine our understanding of ice sheets and sea levels under slightly warmer climate conditions.

Ancient sediment-associated taxonomic profiling: comparative assessment of methods, challenges and opportunities of geomicrobiology from tropical sediment deposits

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The present study is a maiden attempt to extract ancient microbial DNA from a vertebrate fossil context of Pleistocene sediment near the hominin site of Hathnora in the central Narmada valley. The general area and associated stratigraphy are crucial in terms of geological and paleoanthropological relevance. This is the only location in the entire Indian subcontinent where a partial cranium of an archaic hominin species was reported. Subsequent field visits and surveys by numerous researchers have frequently yielded vertebrate fossil specimens from this site's associated cemented sandy-pebble unit. However, several vertebrate fossils were noticed for the first time eroding out (and *in situ*) from the nearby fine-grained sandy-silty deposits of the Baneta Formation at this site, all of which currently appear to belong to an elephant species. Sediment samples were collected for ancient microbial DNA extraction from the same fine-grained context and stratum as the elephant fossils.
Preliminary studies involved kit-based DNA extraction based on bead beating and column-based methods or the use of nanoparticles. The results show that the DNA preserved in these sediments is highly fragmented <100 base pair (bp) in size, degraded, and present only in minute amounts. It contains large amounts of organic matter (such as humic acids) having a high affinity for DNA, thus making DNA recovery from these soil (nanocrystalline aluminosilicate and allophane) sediments difficult and insufficient. As a result, DNA is co-extracted with humic acids, which prevents its amplification in PCR. Mechanical disruption of soil aggregates and microbial cells and various extraction reagents, as required in conventional methods, may further complicate the output. The present paper discusses such difficulties and possible courses of action to overcome such challenges to develop an efficient process that carries out proper lysis of sediments and removes humic acid and PCR inhibitors. Such a method will enhance the downstream processing, such as 16S rDNA-based amplicon sequencing, which further plays a role in studying the evolutionary relationships of the microbial community in a tropical sediment environment.
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INQUA, 14 to 20 July 2023, Rome

Spatial distribution of sedDNA in a small catchment lake: Is a single core enough?

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The interpretation of sedDNA is contingent upon our understanding of transport mechanisms of DNA into the lake sediment. Further investigation is needed to understand how sedDNA represents the ecosystem spatially and how representative a single core is of the catchment. Here we test the homogeneity and representativity of sampling at two spatial scales: 1) at 42 sampling points distributed in a grid with about 30 m distance covering the lake, and 2) by comparing two separate cores taken 30 cm apart at each 42 sampling points. All samples were lake surface sediment (0-2 cm) from a small lake with two basins (Stabbevatnet, Norway). The lake is ideal for this study as it has a distinctive pattern of surrounding vegetation varying from boreal forest and dwarf-shrub heath to agricultural land. Our datasets are: 1) the sedDNA samples collected using systematic sampling method in the lake, 2) a systematic vegetation survey within the catchment surrounding the lake. Our results showed that the deepest part of the lake basins had the highest richness in taxa which is also best-matched the vegetation survey. Both separate cores that are sampled from the deepest part of the lake showed higher richness in taxa separately in comparison to other samples taken from shallower part of the lake. After merging these core pairs, the four sampling points in the deepest part of the lake provided, on average, 64.1% of the taxa in the vegetation survey and whereas the average taxa detected across all sampling locations was 44.5 %. There was also a spatial pattern in the lake sedDNA which reflects the spatial pattern in the vegetation survey, with common taxa in the vegetation found in most samples, while rarer taxa have a more localized detection. Furthermore, the sedDNA samples closer to the lake shore or shallower than 2 m depth have a higher proportion of aquatic macrophytes in comparison to the other samples. Thus, to detect the major vegetation, one core is generally enough, while more cores will allow detection of scattered taxa. To maximize detection, the core should be collected from the deepest part of the lake.

Tracking the expansion of herding practices and landscape transformations during the Neolithic in Central Europe revealed through ancient Environmental DNA

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Central Europe was transformed by agricultural practices during the early Neolithic (~ 7700-6000 cal BP). This process of Neolithisation is interpreted as gradual, with variable progression across ecological mosaics that had been managed by hunter-gatherers since the Pleistocene. The mobility of herding, a key activity for the first agricultural communities, is therefore critical to understand, especially in areas that were peripheral to those favoured for initial cultivation. However, movement of domestic animals across past landscapes can be challenging to detect through analysis of micro- and macro-fossils as these rarely preserve or are difficult to distinguish from wild relatives. In this study, we apply the latest advances in the field of sedimentary ancient DNA to a rock shelter deposit, Velký Mamuťák, with the purpose of further investigating human-environment interactions after the introduction of pastoral land practices, during the Neolithic of Bohemia (Czech Republic). The site is in a sandstone landscape that was heavily forested and unsuitable for cultivation by the earliest Neolithic communities. Here, we find genetic evidence that domesticated animals and their associated microbiomes appeared in the Late Neolithic, around 6000 yr BP, and then persisted through the Bronze Age (3000 cal. BP). We were able to further investigate the mitochondrial DNA phylogeny of key taxa, detecting ancestor lineages of modern domesticated species. Furthermore, we find that the plant DNA record integrates previous botanical results, revealing the persistence of localised forest grazing with gradual transformation of the surrounding grasslands through cultivation. At large, our results suggest that anthropogenic transformations in the peripheral environments of Central Europe did not take place until the Late Neolithic following the expansion of animal management practices.

euka - Rapid characterisation of bilaterian mitochondrial sedimentary ancient DNA using pan-genomics

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Sedimentary ancient DNA (sedaDNA) has become a crucial resource in paleoecology. Ancient data not derived from fossils has vastly improved our ability to gain insight into ecological environments, as well as population structures and movement. However, analysis of sedaDNA has many challenges, including post-mortem damage, contamination, and short fragment lengths, as well as difficulties typical of environmental DNA samples, such as taxonomic identification and abundance estimation of present species.

Bioinformatic analysis of shotgun metagenomic sequenced sedaDNA typically involves alignment against a linear reference genome and the binning of taxa. Both steps can be time-consuming, depending on the amount of data. Additionally, the variety of DNA fragments in sedaDNA samples can make the taxonomic characterisation of eukaryotes very difficult. Contaminated or incomplete reference databases can lead to false-positive or false-negative results. Commonly used binning algorithms apply strict filters to minimise the number of false-positive identifications, however, this can bias against low-abundance species.

We introduce euka, a subcommand of the Vgan suite of tools for pangenomics. Euka is a tool built to quickly characterise sedimentary ancient DNA samples for bilateran mitochondrial DNA. Its foundation is a curated database of mitogenomes in the form of a variation graph reference structure. We make use of the variation graph (VG) toolkit and especially VG Giraffe, which allows us to quickly map large sedaDNA samples against our entire database simultaneously. We analyse our mapping results using an ancient-damage-aware maximum-likelihood framework, allowing for confident low-abundance detection. Euka accepts FASTQ input and outputs a summary of all taxonomic groups present within the given sample, including their respective posterior abundance estimates plus confidence intervals, damage profile, fragment length distribution and coverage. Euka is built to quickly provide researchers with a summary of their sample, which may be fed into a more optimised downstream analysis, thereby reducing time and money spent on computational analysis of sedaDNA samples.

Ancient DNA metabarcoding uncovers the effects of climate change and human impact on Austrian sub-alpine lake, Großer Winterleitensee

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The Alps contain highly biodiverse ecosystems including a large number of endemic flora. As a result of climate change and anthropogenic activities, such ecosystems are at risk from upward vegetation displacement and species loss. To elucidate the effects of climate and anthropogenic activities on plant diversity, multi-proxy vegetation reconstructions have been carried out throughout the Western Alps. However, the palaeoecological history of the Eastern Alps is relatively understudied. Consequently, we are limited in our understanding of how climate and human impact have affected past plant diversity and the formation of the contemporary vegetation in this region. Archaeological research in the Eastern Alps has documented human settlement from ~5.5 thousand years before present (k yr BP) driven by salt and copper mining which has caused significant impact on the ecosystems through mining, deforestation, and pastoral farming. Here, we focus on the Austrian sub-alpine lake, Großer Winterleitensee located at the Easternmost margin of the Alps. We apply sedimentary ancient DNA (*seda*DNA) metabarcoding to reconstruct Holocene plant and mammal dynamics within the lake catchment. Grazing pressure from wild animals had little effect on plant dynamics before the introduction of domestic pasturing to the area. Before this, plant dynamics were driven by temperature and rainfall. *Seda*DNA shows the introduction of domesticated sheep (*Ovis aries*) at ~4 k yr BP. Alongside this, we see an increase in alpine meadow taxa and taxa linked to pasturing activities. At ~1 k yr BP we see evidence of significant tree clearing and a change from pasturing of sheep to cows (*Bos taurus*). Supporting that intensifying human activities since the middle Bronze Age cause artificially low tree lines and enable alpine meadow forbs to persist. Palaeoecological reconstructions of plant biodiversity and their responses to climate change and anthropogenic pressures may be able to provide essential information for future conservation purposes.

Insights, potential, and pitfalls of sedimentary ancient DNA from non-frozen loess at archaeological sites in Alaska

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Sedimentary ancient DNA (*sed*aDNA) has huge potential to expand our knowledge of past human resource use and exploitation from open and near-surface archaeological sites. However, sediment from such sites is often not water logged or frozen, and so the vertical movement of free water through the sediment, coupled with root penetration of overlaying vegetation, has the potential to blur and mix *sed*aDNA signals from different stratigraphic horizons. Here, we generated plant and animal metabarcoding together with shotgun metagenomics data from three archaeological sites and the nearby Chisholm Lake in the Tanana River valley of Alaska. By using the Chisholm Lake record as a positive control for expected plant taxa and levels of ancient DNA damage in sediments of concurrent age, we show evidence for a temporally mixed plant *sed*aDNA signal in the archaeological sediments. On the other hand, sporadic animal *sed*aDNA occurrences in the archaeological sediments closely mirror expectations from site-specific zooarchaeological records, including the detection of burbot (*Lota lota*). This suggests that root penetration may be the dominant driver of cross-stratigraphic *sed*aDNA mixing in non-frozen sediments and that such taphonomic factors should be accounted for when assembling plant taxonomic inventories from these settings.

Paleogentic approaches at the Alfred-Wegener-Institute in Potsdam – tracking terrestrial polar biodiversity

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Terrestrial polar biodiversity is threatened by climate change, which lead to the turnover of communities and variations in taxonomic richness. Within the research area “High-latitude Biodiversity”, the changes in polar biodiversity in response to climate and land-cover variability over the late Pleistocene to present□day warming are investigated. Our work considers ecosystem-level biodiversity with a focus on the diversity of terrestrial and marine primary producers. We use sedimentary ancient DNA from freshwater and marine archives for tracking biodiversity changes.

Our palaeogenetics lab at AWI Potsdam is a part of the larger molecular genetic facility specialized to analyse ancient sedimentary DNA and is thus placed in a separate building away from the modern and recent environmental lab and Post-PCR areas. We established DNA metabarcoding and metagenomics (shotgun and hybridisation capture) to investigate spatial and temporal biodiversity with the aim of identifying the taxonomic and functional composition in Arctic ecosystems.

Next to the some insight into our lab we would like to present the outcomes of two recent studies from our working group.

Climate induced vegetation alterations in Majuli Island (world largest river island) of northeast India from 2150 BCE to 1450 CE: an interpretation based on modern pollen calibrations

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A 150 cm deep sedimentary soil section from the Sakali wetland of Majuli Island (under Indo-Burma Biodiversity hotspot) has been palynologically analyzed to reconstruct the palaeovegetation and past climate in relation to the palaeoflood episodes in Upper Assam, northeast India. Decadal to semi-decadal variations in annual temperature (T_m) and precipitation (P_m) impacted the dense vegetation of northeast India and therefore, surface soil samples and climate data were collected from 25 sites in Sakali wetland for the modern pollen calibration to estimate the role of anthropogenic and palaeoclimatic signatures in the Majuli Island. Regressive transfer function using modern pollen records, and T_m, P_m variation deciphered climate tolerance in fossil pollen assemblage portraying four pollen phases (SW I-IV). During the first phase between 2150 to 320 BCE (4100 to 2270 cal. BP), the relatively dense and consolidated forest has been reflected in Majuli Island under the warm and humid climate with maximum seasonality recorded by the presence of mixed deciduous tree pollen taxa. The recovery of *Rhododendron, Castanopsis,* and Rosaceae in the palynoassemblage is suggestive of the flood activity in the region. During 320 BCE to 860 CE (2270-1090 cal. BP), the conversion of a mixed deciduous forest to open-dry vegetation was witnessed as evidenced by the decline in moist tree cover under relatively less warm and humid climate, corresponding to the Migration Period Cooling (MPC). During the third phase from 860 to 1450 CE (1090-500 cal. BP), the gradual revival of moist and dry deciduous tree elements was observed under increased warm and humid climatic conditions with the advancement of fluvial activities. This phase was very well associated with the Medieval Climatic Anomaly (MCA) which occurred globally from 900 to 1250 CE. Interestingly during the interval from 860 to 1450 CE, the average values of maximum MAP were the highest recorded (≈2500 mm). Since the last 1450 CE (500 cal. BP), striking dipping in MAT (13-22°C) and MAP (464-1364 mm) range was observed indicating the plausible effect of the Little Ice Age (LIA). Furthermore, the scarce occurrence of tree pollen indicates tropical savanna type of vegetation with increased anthropogenic activities.

New pollen-based evidence on climate oscillation during the mesocratic phase of the Eemian in Central Poland (Garwolin Plain)

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High resolution palynological studies on three sites of the Eemian palaeolakes (Kozlow, Zabieniec, Puznowka) in the Garwolin Plain (Central Poland) revealed two types of fossil lakes functioning during the decline of the climate optimum of the interglacial. This last interglacial with no human impact on natural climate variability is correlated with Marine Isotope Stage (MIS) 5e. All the pollen diagrams under investigation recorded seven phases of the Eemian called regional pollen assemblage zones (RPAZs): E1-*Betula*, E2-*Pinus-Betula-Ulmus*, E3-*Quercus*, E4-*Corylus*, E5-*Carpinus*, E6-*Picea-Abies* and E7-*Pinus* phase closing the interglacial pollen succession. Detailed palynostratigraphic investigations (with subzonation) performed on these cores revealed several sedimentation gaps in Zabieniec and Puznowka ones, especially during the hornbeam phase closing the mesocratic period of the Eemian, while at the same time extremely long *Carpinus* phase was investigated in the neighbouring Kozlow profile. The E5 RPAZ, which was divided into four subzones, was interpreted in terms of climate changes (air temperature and humidity). The last subzone E5d (*Carpinus–Picea*), lacking in the Zabieniec and Puznowka sites, was of special interest. Our study evidenced that while no drastic climatic change was recorded in the Kozlow pollen diagram during the decline of the Eemian optimum and sedimentation of gyttja deposits continued until the E7 RPAZ, the other two lakes recorded sedimentary hiatus in the E5d subzone which can be interpreted as significant drop in the water level. The start of the peat accumulation could have been associated there with a drier period and increased continentality of the climate conditions (e.g. greater amplitude between the coldest and the warmest months, and lower precipitation totals) or, on the other hand, the water level drop could have been caused by special geologic-geomorphological situation of the Zabieniec and Puznowka palaeolakes in comparison with the Kozlow one. Conclusions on climate changes during the decline of the mesocratic phase of the Eemian were correlated with the observable climate oscillation towards colder conditions reflected in some German pollen profiles.

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Complex responses of vegetation diversity to Holocene climate change in the eastern Tibetan Plateau

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Biodiversity has attracted much attention recently due to its important relationships with ecosystem function under various global warming scenarios. However, an understanding of biodiversity mechanisms requires study over long time scales. Three high-resolution pollen records of Zoige Basin in the eastern Tibetan Plateau are used to reconstruct changes in vegetation diversity during the Holocene, allowing the mechanisms that drove the dynamic to be quantitatively explored. Rarefaction and Hill's indices are used to estimate the diversity richness and evenness based on pollen data. The results show that changes in palynological richness can be divided into five stages: an abnormal change from 10,500 to 9,000 cal BP, an obvious increase from 9,000 to 6,500 cal BP, a decreasing trend from 6,500 to 4,000 cal BP, an increasing trend after 4,000 cal bp until 1,500 cal BP, and a highly fluctuating stage from 1,500 cal BP to the present. Palynological evenness is relatively stable throughout the Holocene except for during a briefly elevated period from ca. 4,000 to 1,500 cal BP. The result of Boosted Regression Tree analysis indicates that climate is the main driving factor and the effect of temperature is stronger than that of precipitation in the study region. However, during ca. 4,000–1,500 cal BP, palynological diversity is primarily affected by vegetation structure, as shown by an increase in palynological evenness, which can in turn be explained by the climate threshold theory. This research provides a long-term, high-resolution reconstruction of palynological diversity which could be used to infer vegetation diversity change in the ecologically sensitive Tibetan Plateau. The results imply that vegetation diversity in the region may increase under global warming if human impacts are not considered.

Stand scale palynology helps to reveal the role of forest exploitation and climate change in the current distribution of Fagus sylvatica in the NE Pannonian Basin (Hungary)

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The study investigates how past anthropogenic activities and climate change have affected the modern distribution of European beech (*Fagus sylvatica* L.) in Northeastern Hungary. Sediment cores from mesotrophic fen and lake; Black Lake (Mátra Mts., 730m a.s.l.), Lake Egerbakta (Bükk Mts., 280m a.s.l.) were used to study the former distribution of beech at different altitudes. We used sites qualifying for stand-scale studies for pollen and plant macrofossil analyses to detect the local presence of beech. Lake Egerbakta is in an oak-dominated (*Quercus cerris – Q. petrea*) forest today. We expected that before the medieval forest management, beech was likely more widespread at lower altitudes and might have lived in the surrounding forest. Our study on the Black Lake focused on whether beech has been cleared earlier in this region and particularly, when it first appeared >700m a.s.l. during the Holocene. High-resolution pollen and plant macrofossil analyses were combined with ^{210}Pb, ^{137}Cs, AMS ^{14}C dating, LOI, and chemical element analyses (MP-AES). We found a high amount of *Quercus* (40–75%) and very low *Fagus* (1–6%) count in the pollen record spanning the last ~2000 years. We detected forest clearances at AD 1525, 1660 and 1750, and concluded that the Migration Age and Medieval land use did not decrease beech representation at this altitude since it was a turkey oak – pedunculated oak forest zone. We also detected that the Egerbakta lake has been used for hemp-retting since ~AD 900. At the Black Lake (730m a.s.l.), beech expanded and dominated rapidly at ~4500 cal BP and was already substantially cleared during the early Iron Age (from ~2850 cal BP), likely for charcoal-burning and iron-smelting in the region. After its selective removal, our data shows beech being the dominant canopy component around the lake even during medieval times without any considerable clear-cut. Overall, we can conclude that beech forests of the eastern-slopes were not heavily exploited during the medieval forest management period; their old-growthness can be confirmed. Also, the elevation zone where beech forests were replaced by oak due to preference by medieval forest management can be located >300m a.s.l. in the Bükk Mts.

Holocene climatic and vegetation changes recorded in the Late Holocene sediments from Twai Wild Life Sanctuary, Mizoram, north-east India

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The state of Mizoram is the extreme southern region of northeastern India, also sharing its borders with Myanmar. It has three main rivers flowing across the state and reaching towards the Bay of Bengal in the southern ends of the region. The Holocene palaeoclimatic records are absent from this remote location of India. We make an attempt to understand the vegetation and climate variation in this eastern extreme of India during the late Holocene. The impact of Indian summer monsoon is evident in the region having a regional precipitation gradient across the varied topography of the state. The influence of human activities has impacted the vegetation cover in the region. The modern-day practices of slash and burn farming are causing reduction in natural vegetation.A fossil palynological study has been carried out in Late Holocene sediments collected from Twai wildlife sanctuary from a fringe village named Hmuntha, in Aizawl district, Mizoram, north-east India. This record reveals the variations in the vegetation vis-à-vis climate during the late Holocene in the region. The influence of human activities is evident our fossil pollen record and the variation in the paleo-vegetation. The understanding of palaeovegetation shall help us explain the influence of anthropogenic changes on the vegetation in this land-corridor towards East Asia.

Establishing connections between contemporary vegetation distributions, modern pollen representation and the fossil pollen record in the Cape Floristic Region

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Palaeoecological reconstructions provide an understanding of past ecosystem dynamics and climates of a particular area. This understanding can be used to inform conservation and rehabilitation efforts – however, palaeoecological proxy evidence used for these reconstructions (such as fossil pollen) need to be calibrated against a modern equivalent to be interpreted quantitatively. We therefore require an understanding of how pollen is produced and preserved in modern ecosystems, to be able to apply the relevant taphonomic biases to the fossil record. This understanding can be achieved through comparisons of modern pollen rain with surrounding vegetation composition.

Africa, and in particular southern Africa, is an understudied region and severely lacking in pollen calibration data. This study aims to generate the first modern pollen datasets for the southern Cape coast in South Africa, from two case study sites: one is situated in the Western Cape (Pearly Beach, southwest Cape coast) and the one in the Eastern Cape (Nelson Mandela University Reserve, Gqeberha). The pollen calibration data from each site will be used to calibrate fossil records from surrounding areas – this produces more ecologically sound inferences.

The southern Cape coast is important in terms of both biodiversity and human history. Comprising the Cape Floristic Region, conservation strategies need to be optimized for this biodiversity hotspot. It is also the epicentre for a large proportion of the Cape fossil pollen records (which do not have any modern pollen calibration data associated with them). Given the unique context, it is therefore imperative that new pollen calibration data is generated from local sites in the Cape in order to maximize the accuracy and applicability of both palaeoenvironmental research and conservation management efforts.

Long term vegetation dynamics and the climate changes in East Asia

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Past vegetation is considered to be one of the most reliable evidence for recovering paleoclimate changes in palynological studies because it is sensitive to temperature and precipitation during the growing processes. The monsoon played an important role in the high vegetation diversity in East Asia by providing humid air masses from the adjacent seas and the Pacific Ocean. However, questions remain unanswered about how the past sea level and the intensity of monsoon climate have changed over time.
The factors with distinct different distribution zones of vegetation communities, high diversity among vegetation types, and unique topography with low altitude coastal plains all place this area as a favorable region for studying the monsoon climate in eastern Asia. Therefore, in this study, the existed paleoclimate records from northern to South Asia will be reevaluated for a comprehensive understanding of the long-term vegetation dynamics and its response to past monsoonal climate and sea-level changes in East Asia.

Drivers of change: climate variability, stone technologies and prey species in Aboriginal Tasmania and Southwest France.

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The dynamic climate of the Last Glacial Maximum (LGM) is argued to have had a significant influence on forcing technological adjustments and land use adaptations. The argument that the LGM influenced the direction of lithic technologies has had currency in archaeological debates for some time. If this was a general trend in human societies impacted by similar ice age climates, we should see corresponding patterns in the global mid and high latitudes.

We examine this issue with a comparative study of 13C and 15N stable isotopes from human prey animals excavated and dated from Late Pleistocene limestone cave sites (40,000 – 13,000 calBP) in Southwest Tasmania and Southwest France, zones of similar latitude north and south. Stable isotopes from Bennett's wallaby (*Macropus rufogriseus*) and Reindeer *(Rangifer tarandus)* bones were examined to track climate shifts. Interestingly, this evidence shows similar trajectories of climate alterations in the two hemispheres, despite the stable isotopes coming from the two very different species, one placental, the other a marsupial. These two species were the major human prey animal throughout the LGM.

However, the lithic technocomplexes of modern humans in LGM Tasmania and Southwest France are very different, despite the common climatic challenges. In fact, the rapid changes in European Upper Palaeolithic lithic technocomplexes are not mirrored anywhere in Sahul. If climate variability fails to sufficiently explain the styles in lithic technocomplexes during the LGM in the two regions, we ask; what other factors could be at work?

Recent ancient DNA results from Australia and Europe may illuminate this paradox. In Australia there was very little genetic change in human populations over 50,000 years. It was accompanied by period of lithic conservatism lasting from c.45,000 calBP until c.4,000 calBP. In Europe however, human aDNA patterns suggest the rapid appearance of new lithic technocomplexes throughout the LGM that may have been driven by the arrival of new populations in Western Europe. In this presentation we discuss the implications for the climate-lithic technological paradox.

Preliminary results from excavations at two Late Middle Paleolithic open air sites in the lower Besor Basin, northern Negev, Israel

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The Besor basin is the largest drainage system in the Negev desert, extending from the central Negev Highlands and the southwestern Judean hills, and flows into the Mediterranean Sea. The lower segment of the basin is characterized by a series of perennial springs and a savanna like landscape, attracting both animals and humans. During the late Pleistocene the lower Besor basin filled with fluvial loess deposits up to 20 m thick. Subsequent erosion of the loess over the last 12,000 years, resulted in exposure of numerous Paleolithic sites.

In 2020, initial excavations were conducted at two late Middle Paleolithic sites, B37 and B27. Lying under several meters of loess, site B37 is an *in situ* living surface with hearths, rich in stationary finds including fauna and concentrations of conjoinable flint artifacts. In site B27, located 2 km to its north, the archaeological material is embedded within a well-stratified sedimentological layer of fluvial loess, overlain by a thick layer of clay-rich sediments. Although the artifacts at this site are not archaeologically in-situ, they have not been transported a long distance, as indicated by the freshness of their edges, lack of patina and isolated refits.

A critical aspect of prehistoric research in desert environments is understanding landscape evolution, and its influence on past hunter-gatherer mobility and activity patterns. Our ongoing work centers on analyzing the composition of the archaeological assemblages from these two sites. Focusing on the similarities and differences between them, in conjunction with the published nearby site of Far'ah II, opens the way for deciphering land-human interaction in an active and dynamic fluvial system at the edge of the Negev desert.

Shedding light on the mystery Investigating the process of Neolithization in the northwestern Netherlands from the perspective of pollen diagrams

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One of the important periods in human history is the transition from foraging to farming, in short: Neolithization. Neolithization is a gradual acculturation; hence, hereafter we call it "the process of Neolithization". The process of Neolithization of the Netherlands began 5300 years BC, at the time farmers of the Linear Pottery culture settled in the south of the country. Although the Neolithic way of life could spread across the globe rather consistently, it did not have a consistent movement from the south to the north of the Netherlands. So far, prehistoric evidence suggests that after the introduction of farming to the Netherlands, Mesolithic communities in the north, known as Swifterbant culture, did not change their way of life. Swifterbant chose to remain Mesolithic. Since then, for 1500 years, the Mesolithic Swifterbant and other Neolithic cultures in the country lived as known neighbors to each other but on their distinct subsistence.

According to the available palaeobotanical data, Swifterbant eventually obtained cereal and started to grow crop. However, the time it happened for the first is a question to us yet. Furthermore, the reason for switching to the new method of subsistence after 1500 years of adhering to the Mesolithic way of life is still unknown. Either of questions, palaeobotanical records can help us answer our questions by enabling us to reconstruct past vegetation and vegetation changes.

To enrich our understanding of the subsistence and acculturation of Swifterbant of the northern Netherlands, a palynological PhD project began at the University of Groningen. In this project, we strive to enrich our understanding of Swifterbant subsistence and acculturation through palynological analysis of the peat archive of a number of pingo scars near a Mesolithic site in the northern Netherlands.

Keywords: Swifterbant, Palynology, Neolithization, northern Netherlands, pingo scars

Do Early Bronze Age ditches from Oman allow for the assessment of surficial groundwater response time to mid-Holocene climate change?

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In Oman, the Holocene Humid Period lasted from roughly 4,000 to 3,500 B.C., followed by the onset of arid conditions, common to this day, with mean rainfall of about 80 mm/year in the piedmont of the Hajar Mountains (Northern part of Oman). During the Early Bronze Age (EBA; end of the 4th millennium B.C. until the end of the 3rd millennium B.C.), societies in Northern Oman (Hafit and Umm an-Nar Periods) would have faced significant environmental changes that could disturb subsistence strategies and access to water. Water resources are a complex topic in arid regions, because itincludes the understanding of the distribution, collection, and management rainwater, surficial water, and groundwater sources. Prior to the invention/ introduction of *aflaj* irrigation systems in Oman in the first part of the 1st millennium (Early Iron Age), it is challenging to evaluate where and how EBA societies found enough water for permanent settlements. Based on original data from al Khashbah archaeological sites and published data from Salut and Bat, here, we argue that EBA ditches can be used as a marker to observe, at a local scale, the depletion of surficial groundwater level following the Holocene Humid Period. Early Bronze Age ditches from Northern Oman were abandoned/filled by the end of the 3rd millennium B.C. and no longer reused, despite the presence of other structures. We hypothesis that ditches were used to reach a shallow alluvial aquifer in quaternary deposits, and subsequently filled by surrounding material when those structures were disconnected from the aquifer by the decreasing of the groundwater level. This indicates that societies from the EBA benefited from a high groundwater level due to its recharge during the Holocene Humid Period, and that the water table slowly dropped during the 3rd millennium.

Boom and Bust in Late Holocene semi-arid environments of the Channel Country, Queensland Australia

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The channel country of southwest Queensland is characterised by extreme climate variability, particularly in terms of precipitation, which is driven primarily by the El Niño Southern Oscillation (ENSO) phenomenon. High rainfall years are generally associated with La Niña phases, while drought conditions are linked to El Niño events, which generates a 'boom and bust' environment in terms of biological productivity for the region. The Traditional Owners of the region, the Mithaka people were well adapted to this environment through the development of sophisticated subsistence strategies that supported relatively high population densities during the late Holocene period. This presentation will provide the environmental context for Mithaka occupation of the region through palaeoecological and geochemical analysis of sediments from key settlement across their country sites. In particular, this will provide insight into alterations in vegetation dynamics and fire regimes for the late Holocene, which will provide insight into landscape scale anthropogenic management of the semi-arid environments of the channel country.

An exploratory paleoenvironmental study on a coastal Palaeolithic site in Albania through an integrated stratigraphic approach (Dalani i vogël, Vlora)

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The Albanian Palaeolithic is probably one of the least explored periods in the entire archaeological record of the country. This is partly because research on early prehistoric studies is fragmentary, in contrast to a greater focus on later periods. The joint collaboration between the CNR-IGAG (Milano and Rome) and the Institute of Archaeology, Academy of Albanological Studies (Tirana) aims to contribute filling this gap by exploring the paleoenvironment of new/poorly investigated Palaeolithic sites in Albania. The Dalani i vogël site was selected for this purpose from a cluster of coastal sites south of Vlora (Triporti-Portonovo area). An outcrop of ca. 7.5 m high and tens of meters wide was sampled for geochronological analyses (OSL and ^{14}C), magnetic susceptibility, sedimentary proxies (LOI steps, calcimetry, main nutrients), microstratigraphy, micropaleontology and microbotanical analyses.

Fieldwork documented the presence of Middle Palaeolithic flint artefacts within oxidized sandy silt deposits overlying a basal clayey layer developed from the weathering of the flysch bedrock. These lithic finds, initially collected by amateurs and later identified, consist mainly of Levallois cores, flakes and scrapers. Superimposed on this unit is a brownish layer ca. 1 m thick, archaeologically sterile, with a clayey texture class and deep cracks, interpreted as a vertic diagnostic horizon. The top of the unit is truncated by an erosional surface also characterised by a concentration of the mycorrhizal fungus *Glomus* and trilete spores. The overlying unit contains Neolithic pottery. Pollen is sparse and poorly preserved along the sequence, and possibly biased by hydromorphic processes, highlighted by the strong concentration of concentric Fe-Mn Ox nodules. However, the identification of almost exclusively upland herbs (Gramineae, Caryophyllaceae, Cichorioideae together with other Asteraceae) suggests an open and patchy environment throughout the record. Preliminary results of OSL dating point to an age younger than 50 ka for the Palaeolithic industries. Considering the geographical position of Albania, finds pertaining to this particular period are expected to shed new light on the Middle-Upper Palaeolithic transition in Southern Europe.

Reconstruction of tree-line shifts during Late Pleistocene - Holocene time in the summer monsoon dominated region of western Himalaya

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Tree-line fluctuations are an important indicator of climate change. Here we reconstructed the tree-line shift for the past 17 ka BP in the Dokriani glacier valley, western Himalaya, by interpreting the pollen-spore dataset of a 255 m deep subsurface peat sequence from subalpine (3,550 m asl) altitude. We compared the tree-line shifts with glacier retreat episodes in the valley. Presently, the glacier snout is at ~3,900 m asl and the tree-line ecotone is formed by the taxa *Juniperus,* Ericaceae, *Betula*, *Abies* and *Quercus* growing near the vicinity. *Betula utilis* forms the tree-line limit at ~3,700 masl and the conifer limit is formed by the *Abies spectabilis* at ~3,600 m asl. Subsurface pollen record showed that during pre-Holocene (17-11.8 ka BP) the valley was dominated by conifer-steppe vegetation indicating dry conditions. Considering modern pollen and tree-line vegetation relationship as analogue to the past, during the pre-Holocene *Juniperus* sparsely occupied the surrounding moraines. Early Holocene time (11.8–8.3 ka BP) experienced an increase in pollen frequency of *Abies, Betula* and *Quercus* and moisture-loving ground vegetation with a decline of *Pinus*. Moreover, pollen grains of Ericaceae, an above tree-line krummholz taxon, appeared first in the pollen spectra at ~8.6 ka BP. This indicated early Holocene tree-line advancement following the glacier retreat under warm and moist conditions with a strong Indian summer monsoon (ISM). Increase of *Pinus* pollen and decline of *Quercus* pollen during mid-Holocene (~5–3.7 ka BP) probably due to weak ISM coincided with the decline in the rate of glacial retreat. Upper tree-growth limit near the sampling altitude at ~3,550 masl was formed by *Abies* mixed with *Betula* and *Quercus*. Subsequent warming and increase in the ISM corresponding to Medieval Warm Period (1.8–0.9 ka BP) might have helped *Betula, Quercus* and *Abies* to reach current altitudes between 3,500 and 3,600 masl. The cool phase around 0.8–0.2 ka, corresponding to Little Ice Age with enhanced WD, might have resulted in the static tree-line and glacier snout positions. The interplay of climate, topography and edaphic factors remains critical in understanding their roles in vegetation dynamics and needs to be studied temporally and spatially.

Marine dinoflagellate cyst record across the Neogene/Quaternary boundary, Monte San Nicola GSSP, Sicily – preliminary results

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The Plio/Plieistocene (Neogene/Quaternary) transition is characterized by enhanced global palaeoceanographic and palaeoclimatic changes leading to intensification of the Northern Hemisphaere glaciation and emergence of glacial-interglacial cycles, distinguishing the Quaternary period (2.58 Ma). The role of heat transfer, water influxes, and salinity/oxygen fluctuations within the Mediterranean basin reflecting the global changes can be detected by study of dinoflagellates. These single-celled, marine organisms are sensitive to environmental perturbations and produce preservable resting cysts resistant to environmental and sedimentological processes. Total of 404 rock samples spanning the Neogene/Quaternary boundary have been collected across 18 m interval during the GELSTRAT- INQUA-SQS International Field Workshops conducted in years 2021 and 2022. Additional 40 samples will be collected from the ~20 cm Nicola bed at Monte San Nicola representing Mediterranean Precession-Related Cycle 250 coinciding with an obliquity maximum representing Marine Isotope Stage 103, which facilitates global correlation. This sapropelic layer is composed of thick reddish laminated sediment that resulted from particularly high summer insolation/humid conditions. Rich and diverse dinoflalgellate cyst assemblages will be for the first time studied at Monte San Nicola at that ultra-high resolution, providing information about nutrient, salinity, temperature and oxygen level within the basin. The study is being undertaken within GELSTRAT, an international program applying various methods, including palynological, micropalaeontological, mineralogical, magnetostratigraphic, geochemical and isotopic analyses to further our understanding of the Neogene–Quaternary transition at the type area and emphasize the correlative potential of the GSSP.

Environmental forcing across the Neogene–Quaternary boundary at the Monte San Nicola GSSP, Sicily, Italy – preliminary results

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The Global boundary Stratotype Section and Point (GSSP) for the base of the Quaternary System, Pleistocene Series, and Gelasian Stage is placed at the base of a marly layer immediately overlying the Nicola bed at Monte San Nicola, near Gela, Sicily. The Nicola bed is a ~20 cm thick reddish laminated unit and a prominent marker for the base of the Quaternary. As with other Mediterranean sapropels, the Nicola bed is assumed to have resulted from reduced oxygen availability on the sea floor caused by enhanced river inflow during summers: the freshening of surface waters inhibits their sinking in the autumn and prevents the ventilation of bottom waters. In general, oxygen depletion on the sea floor favours the preservation of organic matter within the sediments and also inhibits faunal activity, including bioturbation. To test these assumptions, and refine our understanding of the formation of the Nicola bed, a detailed ultra-high-resolution study of microlaminations, ichnofabrics and mineralogical diversity are being undertaken. The microstratigraphic succession within the Nicola bed can be distinguished as follows: 1) a lower interval characterised by undisturbed primary laminae typical of anoxic conditions; 2) a middle interval dominated by *Chondrites* isp. that cross laminae and indicate a gradual recovery of oxygen levels; and 3) an upper interval containing a low-diversity trace fossil assemblage, including *Chondrites* isp., *Planolites* isp., and *Thalassinoides* isp., that indicates increasing oxygen levels and enhanced recovery of the bottom tracemaking community. The marly interval overlying the Nicola bed representing the base of Quaternary is more intensely bioturbated. Such a pattern represents a progressive change from dysoxic to oxic conditions within the bottom waters during and after sapropel deposition. The present study utilizes thin-section analyses and X-ray tomography to image laminae and trace fossils in three dimensions. Additional mineralogical analyses employing Fourier Transform Infrared (FTIR) spectroscopy will be used for distinguishing the mineralogical composition of the layers. The work is being undertaken within GELSTRAT, an international program applying various methods, including palynological, micropalaeontological, magnetostratigraphic, geochemical and isotopic analyses to refine our understanding of the Neogene–Quaternary transition at the type area.

Effects of human activities on mountain forest in northern China during the middle Holocene

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China has a long history of civilization and agriculture, and its terrestrial ecosystems have long been subjected to anthropogenic impacts. However, we lack detailed knowledge of the nature and timing of human impacts on the development of vegetation ecosystems in the mountain region of northern China during the Holocene, especially during the middle and late Neolithic periods. In this study, we used pollen and charcoal data, combined with the biomization method, from a sediment core from Mayinghai Lake to reconstruct the Holocene vegetation history of a mountain region in northern China. The biome score for forest showed an increasing trend during 11.4–7.5 ka (1 ka=1000 cal yr BP), suggesting the gradual development of a forested landscape during the early Holocene. During 7.5–4.7 ka, the biome results indicate a well-developed forest community which corresponds to the traditional concept of a climatic optimum in the mid-Holocene. During 4.7–2.6 ka, the tree pollen content decreased slightly, and there was an expansion of temperate grassland, dominated by *Artemisia* and Amaranthaceae, and a relatively open forest landscape gradually developed. Considering the relatively warm and wet climatic conditions indicated by independent paleoclimate reconstructions, we conclude that our results provide a record of human impacts on the natural landscapes of the study region since ~4.8 ka (1 ka=1000 cal yr BP), which are mainly indicated by a decrease in the coverage of temperate deciduous forest (based on biomization scores), higher sedimentary charcoal concentrations, and an increase in the number of archaeological sites, both in the vicinity of the study site and throughout the whole of northern China. Our results provide new insights into the role of humans in the ecological evolution of this mountainous region during the Holocene, and we suggest that the impact of prehistoric humans on vegetation succession was potentially significant, which needs to be considered when using pollen records for paleoclimatic reconstruction.

High Tide – Low Tide. Bruges' late-medieval harbour system as a maritime cultural landscape: a sedimentary approach

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Sea harbours and their maritime cultural landscapes are hubs connecting and transferring goods, people and thoughts, and as such connect the local with the global setting and vice versa. Medieval Bruges (Belgium) constitute a classic historical example of such a hub in an international trading system which connected the North Sea area with the Baltic, the Mediterranean and even with the Asian silk route.
As Bruges itself was located inland and had no direct access to the seashore, the connection with the North Sea was assured via a tidal channel, known as the Zwin. Along the Zwin an interconnected system of outer harbours developed. To obtain an overall picture of the medieval maritime cultural landscape along Bruges harbour system an interdisciplinary project was started up, incorporating geological (sedimentological and palaeo-ecological), archaeological and historical research. Research questions such as 'the origin of the medieval Zwin waterway, how the port system interacted with the environment', are tackled for the first time.
Our contribution to the project is the reconstruction of the sedimentary environments developed in the "Zwin area" during the timelapse from the last millennia of the Late Holocene until the decay of the high economic activity in Bruges. The Zwin area hides in his shallow subsurface a complex network of tidal channels composed of several generations of tidal channel systems with varying morphology and sedimentology. The late medieval "Zwin" mentioned in all historical texts is the final one of the many tidal channel systems that developed. Although located in the eastern coastal plain of Belgium, tidal activity did not take place earlier than the Late-Holocene in the area. Together with the sedimentary reconstruction topics like 1) the silting up of the late medieval Zwin, 2) the forcing factors behind the entrance of the Late-Holocene tides in the area, are touched on.

The Long walk to the ‘Neolithic’: Early agro-pastoralists in Tamil Nadu, South India

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The presence of early agro-pastoral communities in Tamil Nadu, southeast India, has been documented since the late 19th c, with sporadic research occurring in the past few decades. Traditionally defined as constituting part of the Southern Neolithic, little is known about processes leading to the appearance or evolution of these communities. Among numerous questions that require consideration, we note aspects of past environments and ecological niches, associated material cultural remains or plants/animals domesticated and chronologies. Further, we know little about transitions from the preceding hunter-gatherers of the early Holocene and relationships with megalithic monuments noted in the same landscapes or with the chronologically simultaneous or subsequent Iron Age cultural phases. Here, we discuss concepts related to classifying cultural phases in the early and middle Holocene in the Indian context. We also review major questions related to early farming communities in Tamil Nadu. We suggest new approaches towards the examination of these cultural phases. We present our recent research in surveys and research at these sites across parts of northern Tamil Nadu, situating these within the framework of the broader South Indian Neolithic and early Iron Age cultural phases. We highlight the behavioural significance of celt-manufacturing strategies in our study region and the significance of past landscape scales of behaviour. Lastly, we highlight long-term continuity in the significance attached to polished stone tools through time, culminating in their ritualistic use in modern Indian villages.

The Rachgoun Prehistoric Coastal Site (Northwestern Algeria), an Upper Pleistocene Occupation : Contribution of Geoarchaeology

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The prehistoric site of Rachgoun (north-western Algerian coast) is an important feature in the knowledge of the coastal quaternary chronology. During the excavation carried out in the last century, it provided a rich archaeological material as well as burials attributed to the Iberomaurusian culture.

In this work, we try to use the multidisciplinary tools of geoarchaeology to decipher the regional stratigraphy of the quaternary surface formations of the lower Tafna basin, which vary between volcanic deposits and coastal dune formations, and the local stratigraphy of the site in order to define the recent prehistoric human occupation in its natural setting.

The first results of recent excavations, prospecting and ancient data associated with isotopic dating allowed us to assign a Pleistocene / Holocene chronology to the site (upper Pleistocene) that corresponds/confirms that the archaeological levels of the Rachgoun site belong to the late Iberomaurusian culture.

Poster - sessions 3, 16, 24, 41, 74, 80, 134, 196

Expression of the stages MIS 13 to MIS 11 in a southern tropical rainforest: preliminary results of pollen analysis of the basin of Colônia, Brazil.

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The Atlantic Forest, situated mostly along the Atlantic coastal margin of Brazil, presents exceptional levels of species diversity and endemism and, it is a key provider of ecosystems services. However, it is extremely threatened by anthropogenic activities and near future global warming consequences. Despite that, little is known about tropical forests dynamics through past climatic variability, e.g., glacial-interglacial cycles. Indeed, long continental records covering deep past times are scarce in South America. Located in the Atlantic Forest domain, the Colônia crater site (23°52´03” S, 46°42´27” W, ca. 700 m a.s.l, São Paulo, Brazil) is a key place to palaeoecological and paleoclimatic studies in tropical region, due its location and its modern climatic setting (under the southernmost influence of the South American Summer Monsoon and polar air advections, as consequence the humidity is distributed all year round). The main purpose of this work is to reconstruct past vegetation dynamics during marine isotopic stages 13 to 11 (~ 533 to 374 ka BP). For that, we analyzed the pollen content of a section (10.58 to 14.62 m) of core COL 17c. The preliminary pollen results show a continuous cool-moist forest expansion during glacial and interglacial times.

MIS12/11 transition and the MIS 11 interglacial in the Alboran Sea: palaeoenvironmental and climatic insights from a high-resolution marine record

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The transition from Marine Isotope Stage (MIS) 12 to 11 (430–400 ka BP), is regarded as one of the largest shifts in climatic conditions over the last 900 ka. This period is particularly important as it represents a phase of innovation for Hominins. We present here a high temporal resolution pollen record that encompasses the period between MIS 12 and MIS 10 (433–365 ka BP), recovered from the ODP Site 976 in the Alboran Sea. This study aims to provide new insights into the response of vegetation in climatically sensitive region, and to highlight changes in seasonal aridity and precipitation in the continent during the MIS 12/11 transition and MIS 11 interglacial. Pollen-based quantitative reconstruction techniques (MAT, WA-PLS and BRT) were implemented to produce climatic reconstructions for this period.

The ODP Site 976 pollen record shows the shift from glacial to interglacial, highlighted by the transition from predominantly herbaceous and steppic taxa and a high abundance of *Pinus*, to an assemblage comprised of temperate and Mediterranean taxa. The climatic reconstructions show a significant rise in mean annual temperatures and precipitation. A climatic optimum for temperate and Mediterranean taxa is identified between 420–405 ka BP, equivalent to MIS 11c and synchronous with maxima in temperature, precipitation and insolation. Substage MIS 11b, characterised by an increase of *Pinus*, *Cedrus* and steppic taxa is reflected by a drop in temperature and precipitation. Finally, substage MIS 11a was determined as a period of increased variability characterised by fluctuations in forest communities and high-amplitude changes in temperature and precipitation towards the MIS 10 glacial.

Our record from ODP Site 976 provides evidence for the strong climatic transition during Termination V. Our results confirm the intense shift during the MIS 12/11 transition and show that this region is uniquely sensitive to millennial-scale climatic variation during MIS 11. The abrupt shifts in vegetation observed in this record may be used to infer that Hominins, particularly the ancestors of Neanderthal, would have had to adapt to these climatic shifts and fluctuations by finding new strategies of subsistence and technologies.

Sensitivity of Caucasus Glaciers to Regional Climate Change

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The glaciers of the Caucasus (Georgia) have undergone significant changes against the background of global warming. Most of them have disappeared, and some have suffered degradation. The glacier area has decreased during the retreat, but at the same time the total number of glaciers has increased. Generally, the glaciers play a major role in formation the water balance of the region and their reduction or disappearance poses significant damage to the natural ecosystems and economy. This article presents an analysis of the change in the surface area of the glacier using multitemporal data sets for the Greater Caucasus, based on manual digitization of large-scale (1:50,000) topographic maps of the 1960s. and satellite images of 1964 (Corona), 1986 (Landsat 5) and 2014 (Landsat 8, ASTER). The paper deals with major meteorological factors operating on glaciers and the melting of direct solar radiation on the basis of the melting energy model of the Enguri basin glacier. Modern climate change is characterized by fluctuations in the balance of radiative energy in the lower troposphere, which determines the process of fluctuations in glaciers (melting of the thickness). Since the interaction between glacier and climate is a complex non-linear process, we use mathematical modeling to predict the future adaptation of Georgia's glaciers to current climate changes. With the help of a two-dimensional mathematical model of the dynamics of changes in the thickness of the glaciers, the configuration of the upper surface of the Caucasus glaciers were studied. Some typical problems of mathematical and numerical modeling of glaciers are discussed. For the first time, with the help of mathematical modeling, the process of melting of the Caucasus glaciers (Kazbegi 5030m) was estimated. Some simulation results are presented and analyzed.

Northwest African monsoon strength, ecosystem variability and wind patterns during the Mid-Pleistocene Transition

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Proxy and model evidence suggest that Northwest Africa transitioned from a wet landscape covered with expansive vegetation during the Pliocene toward drier and less vegetated conditions during the late Pleistocene, however, our understanding of the nature of this transition is hampered by a paucity of paleo-records that bridge these two well-studied intervals. The Mid-Pleistocene Transition (~1.2–0.9 Ma), during which glaciations intensified and increased in duration, is perhaps one of the most important yet poorly understood global climate reorganizations of the past several million years. Here we generate new plant-wax isotope as well as dust and opal flux records from ~1.1–1.0 Ma to evaluate both the orbital-scale controls of Northwest African hydroclimate and vegetation during the MPT and, in context with previously published records, the drivers of long-term climate and ecological trends over the Plio-Pleistocene. The tempo and magnitude of the Northwest African monsoon rainfall variability closely track changes in cross-equatorial moisture transport related to low latitude insolation gradients. However, a pronounced decline in monsoon strength following the MPT was most likely forced by an increase in Atlantic meridional sea surface temperature gradients. The northward extent of grassland, savanna and forest ecosystems in Northwest Africa do not linearly track changes in monsoon strength, but are more likely influenced by changes in rainfall seasonality and ecosystem disturbances. Synchronous declines in dust and opal flux unrelated to changes in rainfall are consistent with equatorward migrations of wind belts as the pole-to-equator temperature gradient increased in response to high-latitude Northern Hemisphere cooling since the MPT.

Contrasting vegetation response during Heinrich events 4, 5 and 6 in Western Europe

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The amplitude, timing and duration of the European vegetation responses to orbital and millennial-scale changes, in particular to the major episodes of North American iceberg discharges, the so-called Heinrich events (HEs) that punctuated the Last Glacial Period (~115- 27 ka) are still poorly known.

The multiproxy study, pollen and planktonic assemblages, sedimentological and geochemical analyses of two deep-sea cores retrieved in the Bay of Biscay (MD04-2845, 45°21'N, 5°13'W) and the Gulf of Lion (MD99-2343, 40°29'N, 4°01'E) reveals the vegetation and climatic changes of southwestern and southeastern France to the HEs 4, 5 and 6. These records are well chronologically constrained by numerical dating (new IRSL ages for the MD04-2845 deep-sea core) and new age-depth models, based on Bayesian statistics and stratigraphic constrains. They show different magnitudes in the semi-desert expansions in response to HEs 4, 5 and 6. In southwestern France, the development of the semi-desert is more pronounced during HE 6 compared to HE 4 and 5, while in the southeast HE 6 is marked by an exceptional and still unexplained strong forest development. In this later region, HE 4 allowed the development of a more forested landscape compared to HE 5. The comparison of our results with other well-dated terrestrial records show similar vegetation and climate patterns. The contrasted vegetation responses during these events appear to be the result of different intensities of the thermohaline circulation and local oceanic processes associated with the instability of the Laurentian ice sheet.

Investigating uplift driven diversification of the Kashmir Himalayas using multiproxy data

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Topographically complex regions, such as large mountain ranges, feature hotspots of biodiversity that reflect geological influences on ecological and evolutionary processes. A popular but little-tested hypothesis is that tectonic uplift creates environmental conditions. that increase the rate at which resident species divide and evolve to form new ones. Thus, one of the most common hypotheses for rich biodiversity found in mountains is uplift driven diversification known as orogeny, which creates conditions that favor rapid in-situ speciation of resident lineages. Testing hypothesis about how these topographic diversity gradients arise, persist, or diminish requires demonstrating coincidence and interaction in time and space between causal factors and biogeographic responses. The regional phytolith records and other sediment proxies along with the rate of uplift of the mountainous regions may provide evidence for this spatial and temporal turnover of the paleo-vegetation and geographic distributions respectively. The current investigation analyzes multi-proxy data including phytoliths, sedimentological (e.g., grain-size), magnetic susceptibility and geochemical data (e.g., TOC, C/N ratio, element composition) as well as the chronology of a representative sedimentary sequence (Shankerpora section) along with the rate of uplift to get insights for the uplift driven diversification in the Kashmir Himalayas. This approach will help us to trace the histories of multiple groups of plants and to infer the tempo (rate) and mode (colonization versus in situ diversification) of biotic assembly through time and space during the Late Quaternary in the high altitudinal ranges of the Kashmir Himalayas. This study will be a base for future paleoenvironmental and paleoclimate investigations using phytoliths from regional sediment archives in high-mountain ranges.

Polyaromatic hydrocarbons in a deep lake sediment core from eastern Romania

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We present here preliminary polyaromatic hydrocarbon (PAH) data measured from a 60 m long sediment core from Obanu Mare paleolake (SE Romania) that spans several glacial-interglacial cycles. As most PAHs are generated during the burning of organic matter, high molecular weight PAHs can be useful proxies for fire intensity while low molecular weight ones could be used to studying past fire activity. Also, in certain conditions, several PAHs are generated by geogenic processes and are a common occurrence in hydrocarbon deposits. Following accelerated solvent extraction, PAHs were determined by liquid chromatography using a fluorescence detector. Predominantly were identified high molecular weight PAHs (dibenz(a,h)anthracene, benzo(g,h,i)perylene, and indeno(1,2,3-C,D)pyrene) but low molecular weight PAHs such as fluoranthene, pyrene or benz(a)anthracene were also present. While Obanu Mare dried out at some point in the past, other similar neighboring lakes are still active and are fed by mesothermal water rich in H_2S and CH_4 whose origin lies in deep hydrocarbon deposits. The water table of the sulphidic aquifer is controlled by the nearby Black Sea level and by identifying geogenic PAH indicators in sediments we should be able to constrain periods with high sea level stands. Moreover, during periods with pyrogenic origins of PAHs, we can reconstruct the local fire history and contribute this information to the multi-proxy paleoenvironmental reconstruction of this region.

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Application of Non-destructive Core Scanning Techniques on Characterizing Turbidite Sequence

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Turbidites in marine sedimentary records have been widely used to infer extreme events, such as earthquakes, submarine landslides, tsunamis, and floods. Characterizing such event deposits with their triggering mechanisms becomes the critical step to infer long-term event risk. In this study, more than 700 turbidites have been identified based on the optical and computed tomography (CT) images in a 12.77 meters long core MD18-3538, which was retrieved from the distal part of the Taitung Submarine Canyon off eastern Taiwan. A data-driven approach to objectively classify the characteristics of turbidites thus was developed by combining multivariate statistics (i.e., principal component analysis, PCA; cluster analysis, CA) with non-destructive core scanning techniques (i.e., multi-sensor core logger, MSCL; XRF-scanning; spectrophotometer reflectance; and CT). The results show that turbidites in core MD18-3538 can be characterized by higher density, P-wave velocity, and XRF counts of Ca and Sr. Moreover, the turbidite layers can be further divided into layers with high and low magnetic susceptibility. An entropy analysis using CT images was performed to further study the internal structures of these turbidites to provide detailed structural information and, eventually, its sedimentary dynamics. This study offers new prospects for turbidite classification off eastern Taiwan and other places with similar geological settings. The triggering mechanisms of turbidites can therefore be further disentangled, and the complete event history of the region may finally be reconstructed.

The fate of aragonitic pteropods preservation in the late Quaternary sediments of the Indian Ocean

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Pteropods are marine gastropods made up of aragonitic shells, a metastable polymorph of $CaCO_3$, which is more susceptible to dissolution than calcite. Hence, their preservation and accumulation on the seafloor are controlled by the aragonite compensation depth and changes in the properties of water masses. The analyses of the late Quaternary pteropods preservation records from the Indian Ocean reveal characteristic changes in the water masses and water column chemistry from the last glacial period to the present. Generally, better preservation is reported during cold periods and very poor preservation during Holocene. The poor preservation during the present interglacial is a subject of interest since they are the most vulnerable among the major plankton producers of $CaCO_3$ in the current ocean acidification scenario. The recent changes in the aragonite saturation depth (shoaled significantly by 25-155 m) in the Indian Ocean due to the absorption of anthropogenic CO_2 in the subsurface water masses and also due to increased organic matter decomposition rates. Modern aragonite preservation has dropped nearly as low as those experienced in the late Pleistocene interglacial periods. However, pteropod preservation is better during the last interglacial period (Eemian). The poor preservation/absence of pteropods during the Holocene in the Indian Ocean may have implications on ocean acidification driven by enhanced atmospheric CO_2 concentration. The preservation spikes are present in all the records, which are well correlated with time. The last preservation spike was during the deglacial period, consistent with Atlantic and Pacific Ocean records. The deglacial preservation spike indicates the global nature of deepening aragonite compensation depth, changes in water column chemistry, and intermediate water circulation

Flooding and anthropogenic influences on artificial lakes in the Red River Delta

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Artificial lakes and wetlands created for ecological conservation or to store water for anthropogenic use require careful management to prevent changes to water quality. In highly dynamic environments of tropical mega-deltas, such water environments are susceptible to seasonal variations in hydroclimate and extreme weather events. It is therefore important to understand how climate change may impact artificial lakes. In addition, rapid urbanisation and its associated anthropogenic activities pose high risks to water quality through nutrient enrichment and industrial pollutants. The Red River Delta (RRD) in northern Vietnam is highly vulnerable to projected changes in climate and is experiencing high rates of population growth. Monitoring of contemporaneous water quality in some artificial lakes meant for human consumption or in the wider catchment is ongoing by resource managers in the RRD, but there is a lack of long-term data to assess trends in changing hydrology and flooding in lake and wetland catchments. Moreover, little is known about the impacts of anthropogenic activity on aquatic ecosystems, making palaeolimnology an essential tool for lake and wetland managers to provide longer term trajectories of change. In this study, we use multiple sediment cores recovered from artificial lakes in the Ninh Binh and Hanoi provinces. Radiometric dating using 210Pb has established geochronology and multi-proxy analysis to establish flood histories and ecosystem change using particle size analysis, magnetic susceptibility, XRF, and pigments to assess water quality changes over the recent past are presented.

Towards a quantitative reconstruction of past environment: Cladocera training set.

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Lakes are important components of post-glacial landscapes, sensitively responding to environmental changes on a local and global scale. Lake catchment characteristics, such as land cover and land use, have a direct impact on the amount of nutrients reaching the lake waters and therefore also on the trophic status of lakes. Global processes shaping the climate also play an important role in shaping the physicochemical processes in lakes. The current state of the lake ecosystem is recorded in sediments that constantly accumulate at the bottom of water reservoirs. In the lakes of north-eastern Poland, sediments have accumulated since the end of the last glaciation. The source of information about the past are the physical and chemical characteristics of the sediment, as well as the remains of organisms living in the lake. The remains of planktonic organisms such as Cladocera are considered as reliable bioindicators. They respond to changes in many environmental parameters and are commonly found in lake sediments. Therefore, they are used to create quantitative reconstructions of selected environmental parameters, e.g. total phosphorus, temperature, water depth. However, to make this possible, it is necessary to create a database, a training set, including the results of in-situ measurements and laboratory analyzes of contemporary lake water parameters and the species composition of local biocoenoses preserved in sediments. Then, using statistical methods, the relationship (transfer function) between environmental factors and the composition of the population is determined. This approach has been successfully applied in paleolimnology in recent years, but there are few such test sets in Central-Eastern Europe. To enable quantitative reconstructions using Cladocera we created a new training set consisting of 64 lakes located in north-eastern Poland. The selected lakes represent a wide range of trophic states (from oligo- to eutrophic). The test set will be used to better understand and assess the impact of climate change and human activity on the current state of the lakes. The research was fully founded by the NCN research grant 2016/23/D/ST10/03071.

The use of modern diatom assemblages in paleoenvironmental reconstructions

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Lakes sediments are excellent archives of physical, chemical and biological conditions of lakes. There preserve remains of organisms that lived in the water column and therefore. represent communities of entire lacustrine habitats. They reflect seasonal changes as well as spatial differentiation. The most important bioindicators related to the lake environment include diatoms and Cladocera. Both indicators are essential components of plankton. They respond to environmental changes such as nutrient concentration, pH, access to light, and temperature and are common in aquatic environments. This species composition is the basis for the quantitative and qualitative reconstruction of past environmental changes.
In recent years, the use of advanced statistical methods has been of great importance in the paleoecological studies of lakes. Transfer function aproach is among most commonly used for the quantitative reconstruction of various environmental variables. For this purpose, scaled training sets are created that combine modern assemblages e.g diatom, physicochemical parameters of water along with the ecological gradient of interest to us. Knowing the environmental factors that affect the presence and abundance of individual taxa in contemporary biocoenoses, it is possible to reconstruct the conditions previously prevailing in the reservoir using statistical methods.
We will present a new diatom test set consisting of 64 lakes located in northeastern Poland. The selected lakes represent a wide range of trophic statuses (from oligo- to eutrophic). Such studies are essential to understand the relationship between dominant taxa, phosphorus concentrations and other environmental variables, enabling long-term observations of lake eutrophication changes. This is of crucial importance in the context of protecting water resources. It will also be possible to trace changes in the eutrophication of lakes from the last glaciation to the present day and thus determine the impact of climate change or man on the increase in lake productivity. Knowledge of the ecological requirements of diatoms from various habitats (pelagic, sublittoral, and littoral) will also be supplemented, increasing the precision of paleolimnological reconstructions based on the analysis of their species composition.
The research was fully funded by the NCN research grant 2016/23/D/ST10/03071.

Vegetation dynamics in a cultural landscape from Late Pleistocene to Holocene

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We compare vegetation and fire records from four sediment cores from the Mersey River valley in northern lutruwita/Tasmania, Australia to explore vegetation stability during the Holocene. The records span a range of time scales from >60,000 years through to the last 4000 years and reveal the nature, pace and drivers of vegetation change at a range of time scales and sample resolution within the same cultural landscape. The sites are located within dry eucalypt forest and woodland with some pockets of wetter forest and this appears to have been stable throughout the Holocene, despite climate change during that period, and likely reflects the ongoing maintenance of the cultural landscape by Aboriginal people.

Morpho-sedimentary structure of new mud volcanoes on the Moroccan Atlantic continental margin (Gulf of Cadiz)

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Multibeam bathymetry, sub-bottom parametric profiler, multichannel seismic reflection data and sediment cores were used to detail the nature, morpho-sedimentary and internal structure of five newly discovered mud volcanoes (MVs) in the Moroccan margin of the Gulf of Cadiz. The Henriet and Subvent MVs are located at 300-400 m water depth, while Chueca, Demetrio de Armas and Puerto Real MVs are at 1100-1800 m water depth. Two main types of morphologies are identified: regular cone-shaped edifices (Subvent MV) with a pronounced crater (Henriet MV) in the eastern province; and ridge- attached oval-shaped conical edifices (Chueca, Demetrio de Armas and Puerto Real MVs) in the western province. The overall seismic architecture of these MVs is the result of successive events of mud extrusion and outbuilding alternating with periods of dormancy. The Henriet and Subvent MV system is composed of stacked bicones and intrusive complexes, which penetrated upper Miocene-Quaternary sedimentary units rooted in the Gulf of Cadiz wedge. Major phases of mud extrusion and outbuilding took place since the Late Pliocene with re-activation during mid-Pleistocene. Mud breccias interbedded with hemipelagic/contourite sediments were collected for all MVs. Cores attest recent periods of mud outflows lasting from the Late Pleistocene (180 ky) whereas the end of MV activity could date back to historic times (the last 0.8 ky). The most active MV points out to the Subvent MV. These new MVs are formed in response to the extensional and compressional system within the Gibraltar Arc. In the eastern side, MVs are related to extensional faults forming deep sedimentary basins and forcing overpressured fluids to migrate upwards coeval with thick contourite deposits. On the western side, MVs are related to compressional ridges at the front of fold-thrust systems which act, as pathways to deep-seated fluids to ascent to seafloor

Geomorphic and acoustical signatures of hydrothermal vents in the Calent mound, Columbretes Islands (western Mediterranean Sea)

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The Columbretes Islands are a volcanic archipelago located in the southern sector of the Ebro continental shelf in the western Mediterranean composed by four islands, islets and small submarine mounds and peaks. Two oceanographic expeditions were carried out in the area during 2020 and 2021 supported by LIFE-IP-INTEMARES project. During the expeditions, several datasets were obtained: (i) Multibeam echosounder (Kongsberg EM710) bathymetry and backscatter, (ii) water column data were recorded and they have been used to detect and compare acoustic flares, (iii) very high resolution parametric profiles (TOPAS PS18) and (iv) several rocks and superficial sediment samples by divers and shipek dredge, respectively. All these data has allowed characterizing the geomorphology of Calent mound (in the south of the archipelago) and the study of the fluid venting processes that nowadays are active in the area. Calent is a rounded mound of 1.2 km wide and 40 m high located between 37.5 and 80 meters depth. Several outcrops in the summit, up to 2 m high, showed the highest backscatter values. A total of 24 acoustic flares were detected with heights between 20 and 40 m revealing a release of gas from the seafloor into the water column. Also, gas bubbles have been observed and filmed by divers in the flares at 40 m depth. Crusts are present as fine-grained deposits composed of iron oxyhydroxides. Some of the sediment samples obtained from the base of the flares, once on board, emitted a strong odor of hydrocarbon. They are composed mainly by biogenic coarse sands and gravels with a carbonate content from 25% in the base to more than 40% in the summit. In the very high resolution parametric profiles, several micropockmarks (about 1 m diameter) have been observed as small disruptions in the most superficial continuous reflectors. These microstructures are not related to the acoustic flares observed and could indicate active flows in the recent past that now are inactive. The results observed indicate that the Calent mound is the most active hydrothermal volcanic area in the Spanish western Mediterranean.

Morphometric analysis of mud and fluid migration morphology documented offshore Scoglio d'Affrica islet (Tuscan Archipelago, Northern Tyrrhenian Sea)

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Mud and fluid migration producing active seepage at the seafloor is a global phenomenon documented in different geodynamic contexts. Scoglio d'Affrica islet is part of the Elba-Pianosa Ridge, a N-S morpho-structural high, where submarine methane emissions have been studied since the 1960's and where violent gas outbursts such as that in 2017 are documented. The first morphometric analysis of positive and negative mud and fluid migration morphologies occurring in study area by means of high-resolution bathymetric data is presented in this work. Mud and fluids, migrating through a thick Eocene-Early Miocene siliciclastic succession and overlying sedimentary layers form a number of positive morphologies including seven large sub-circular mud volcanoes with steep flanks, up to ~ 400 m wide, and up to 35 m high. Their morphometric parameters (e.g., flatness value) allow us to interpret, classify the mapped positive morphologies as mounded, flat topped and conical shape features. Moreover, a crude mathematical approach based on buoyancy-driven model, usually applied to igneous volcanoes and successively developed for submarine mud volcanoes on Earth as well as on Mars, allows to calculate the mud source depth, resulting in shallow reservoirs. As regarding negative features, more than 250 pockmarks with planform shape from sub-circular to elongated and U/V-shaped cross-section have been mapped. They are mostly arranged as isolated, in clusters or organised in N-S oriented strings, running almost parallel to the fault escarpments which represent the main structural features of the area. Pockmarks have been classified based on their size parameters (i.e., depth, mean diameter) according to the more recent literature. Considering the probability of mud volcanoes explosive activity, the high-magnitude outburst occurred in 2017 and the shallow water setting, the morphological characterization of fluid seepage features is also an important baseline study since it can provide insight for marine geohazard assessment.

Seafloor fluid vents imaged by multibeam versus 3D seismic datasets : a comparison from the Amazon deep-sea fan

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High resolution bathymetric datasets of the deep seafloor continue to offer new perspectives on the processes and products of seafloor fluid venting to the ocean. On the Amazon deep-sea fan, multibeam hydroacoustic data acquired across the upper slope by SeaSeep in 2016 have previously been shown to reveal dozens of water column gas flares, most rising from low seafloor mounds associated with higher reflectivity. Here we compare examples of seafloor fluid vents in a ca. 200 km^2 area of the upper Amazon fan in water depths of 1000-1200 m, observed on the SeaSeep multibeam imagery (peak frequency 12 kHz, 30 m grid resolution) and on seafloor extracts from an exploration 3D seismic volume (peak frequencies ≈40 Hz, 10m grid resolution). The two datasets reveal a variety of seafloor features, including mounds, depressions and mounds within depressions, with relief of up to tens of meters and widths of hundreds of meters. The high frequency content of the multibeam data provides information on the seafloor and near-seafloor sediments to depths of a few meters, and reveals subtle morphological features and changes in reflectivity, including possible sediment flows. The much lower frequency content of the 3D seismic data integrates the upper 10-15 m sub-seafloor, but its higher spatial resolution nonetheless reveals surprising additional details of seafloor morphology. Together these datasets show that the morphology of the mounds is consistent with small mud volcanoes, some with crater-like depressions at their summits; some mud volcanoes sit in larger depressions interpreted as calderas due to localised subsidence, while a few isolated (unfilled) depressions may be either calderas or pockmarks. The Amazon fan is an area of high sedimentation rates, and the observation of relatively small positive- and negative-relief seafloor morphologies, and local high backscatter signatures, suggests recent extrusive activity. However, only a few of the mud volcanoes coincides with water column gas plumes imaged in 2016, possibly indicating episodic activity.

REVEALS-based reconstruction of changes in vegetation cover during the last interglacial – a case of the Wola Starogrodzka site, E Poland

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We present the first (and probably also for the whole of Central Europe) quantitative pollen-based reconstruction of changes in vegetation cover during the Eemian Interglacial (last interglacial, MIS 5e). We describe these changes using the Regional Estimates of VEgetation Abundance from Large Sites (REVEALS) model. REVEALS has been applied to 6 profiles from the Wola Starogrodzka site, E Poland (a large number of profiles produces more reliable land-cover estimates with lower standard errors) to reconstruct the percentage cover of 21 plant taxa assigned to 9 plant functional types and 3 land-cover types. Due to the impossibility of determining the absolute age of studied sediments (their age is beyond the limits of the radiocarbon method), the windows for reconstructions are not time windows, but they are biostratigraphical windows determined on the basis of a detailed regional palynostratigraphy of the Eemian Interglacial. In Poland, seven regional pollen assemblage zones were distinguished (E1 to E7 R PAZs). This division well corresponds to other European regional palynostratigraphies, that enables the correlation of regional pollen zones across Europe. Almost every Polish regional pollen zone is divided into 2-4 subzones (R PASZs) – a total of 24 R PASZs is distinguished. They are, in this study, the windows for a REVEALS-based reconstructions. Each such window groups all the pollen spectra representing it in all analyzed profiles from the Wola Starogrodzka site.

Issues related to the interpretation of the results in terms of landscape openness and climate-induced vegetation changes are discussed. We showed, for example, that the land-cover of open communities throughout the early Eemian (E1-E3 R PAZs) was much larger than we previously estimated on the basis of the percentage pollen data. On the other hand, the land-cover of *Carpinus* in the hornbeam phase of the middle Eemian (E5 R PAZ) was significantly smaller than we had previously assumed.

This is followed by a review of the future potential utility and development of this reconstruction for the Eemian Interglacial.

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Enhanced late Quaternary pluvial episodes in south-eastern Australian highlands during glacial episodes as revealed by optical dating

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Fluvial sediments in Australia provide important archives for assessing late Quaternary flow regime changes. In south-eastern Australia abundant evidence exists of enhanced runoff conditions throughout and beyond the last full glacial cycle. These include palaeochannel deposits and fluvial terraces which were interpreted as evidence for pluvial episodes and enhanced flow regimes. The hydrological setting in the east of the Great Dividing Range is characterised by a series of smaller coastal-draining catchments (< 1000 km^2) surrounded by much larger basins extending to the west of the great escarpment and with areas > 5000 km^2, such as the Hunter and Shoalhaven. Recent single-grain (SG) optically stimulated luminescence (OSL) study on three fluvial terraces in the upper Hunter catchment showed that extreme fluvial aggradational episodes in the catchment are mainly correlated with glacial or stadial periods since MIS 6. This study presents the latest OSL dating results of several previously undated fluvial terraces in the Shoalhaven and upper Hunter catchments, namely the Larbet terraces, the lower and upper Mayfield terraces. SG quartz and/or SG K-feldspar dating were applied to fluvial sediments collected from these terraces. These include several challenging samples in terms of luminescence dating, exhibiting complex luminescence properties and/or strong bioturbation, or are close to signal saturation. A comparison between SG quartz and feldspar equivalent dose distribution was used to assess the extent of bleaching for individual samples and to select the most reasonable dose population for age estimation; new statistical models were used to provide more reliable chronologies for samples near saturation. Our dating results extend the fluvial sedimentary record in south-eastern Australia to Marine Isotope Stage 8. These new chronologies, together with previously published data, suggest that enhanced river valley aggradation in the south-eastern Australian highlands took place mostly during glacial or stadial periods throughout the late Quaternary. Phases of valley-floor aggradation in south-eastern Australian highland are inferred to be a function of increased sediment supply during the cold periods in the late Quaternary, resulting from strong periglacial activities in the adjacent Australian highlands.

Seasonal variances in the palaeolake of Tayma (Saudi Arabia) seen in Ostracoda and Foraminifera during the Early Holocene Humid Period

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Tayma in Saudi Arabia is an important archaeological and historical oasis city, with Neolithic finds and an almost permanent settlement history since the Early Bronze Age. During the Early Holocene Humid Period (EHHP), a perennial lake was located in the endorheic depression north of the modern settlement. While the climate in this area is arid to hyperarid today, it was arid to semiarid during the EHHP. A deep lake phase occurred around the 8.2 ka BP climate deterioration that led to general cooling and drying on the Arabian Peninsula. Foraminifers and ostracods in the sediments of the sabkha basin represent a brackish to hypersaline inland water fauna, which provides valuable information on the past precipitation/evaporation balance. In the lower part of an analysed core section from the deepest part of the basin, they reflect the beginning of the EHHP with a transition to a more humid phase and the development from slightly saline wetlands to a shallow brackish lake, shown by increasing microfossil abundances, a decreasing adult/juvenile-ratio in ostracods, and an increase of δ^{13}C. This culminated in a deep lake phase at ca. 8.3 cal. BP. Varved sediments from two sections contain ostracods (*Cyprideis torosa*) and foraminifers (*Ammonia tepida* and *Quinqueloculina seminula*) which are more abundant in the dark layers, indicating more favorable living conditions during deposition of these layers. This is also indicated by higher frequencies of juvenile carapaces in the light layers, suggesting possibly higher juvenile mortality rates. A sieve pore analysis in *C. torosa* valves proposes distinctly higher salinities during deposition of the light layers. The seasonal variances in the microfossil assemblages may reflect generally dry summers and more humid winters, a seasonal pattern preserved within the alternating varves.

In the uppermost part of the section, a decrease in both microfossil and macrofossil frequency, and stable isotopes in the ostracod shells indicate the transition to drier conditions in the mid-Holocene, at ca. 8.1–7.9 cal. BP.

Agropastoral practices and water stress in Central Asia: first insights given by the lake sediment sequence of Kanbeshbulak (Hissar mountains, Uzbekistan)

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This contribution aims to analyse what were the adaptation strategies of agropastoral systems vis à-vis water stress over the last millennium in Central Asia. Based on paleoenvironmental analyses carried out on the sediment infilling of Lake Kanbeshbulak (southern part of the Hissar mountain range, Uzbekistan), we will reconstruct the long-term variability of soil erosion (sedimentology and, elemental geochemistry) in relation to indicators on the nature and relative intensity of the agropastoral practices (palynology carried out on the same cores). Those results will be put into a Human perspective through comparisons with historical sources. In particular, we will propose a special focus on the Medieval Islamic Period to discuss the hypotheses that regional climate changes, by modifying water resource availability locally, might have impacted crops and pastoral livestock productions, triggering economic losses and social contestations unevenly addressed by the succeeding political powers.

Aridification in Mid Holocene in the south-eastern Mongolia

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There are many depressions with lacustrine terraces in the south-eastern Mongolia. This area is located at the summer monsoon limit without glacier melting water. This means that the climate of the eastern Mongolia is strongly affected by strength of summer monsoon due to climate change. The present study aims to elucidate palaeohydrological environment change of the south-eastern Mongolia through analysis of lacustrine terrace deposits (Uidzegiin lake and Bolgoin Govi). Uidzegiin lake is located at the Ongon Soum, the south-eastern Mongolia. These depressions are desiccated saline lake with highest lacustrine terrace (1070m a.s.l.). The lacustrine terrace is widely distributed around present Uidzegiin lake and Bolgoin Govi (Palaeolake). Sudden coarsening of lacustrine deposits shows the sudden lowering of lake level surface associating with reduction of contents of biogenic silica and organic matter. This event is dated around 5,000 yrBP by 14 C dating. Because this area is stable tectonically without influence of glacier melting water, this means that the precipitation of this area reduced suddenly in the Mid Holocene. On the other hand, the climate of this area was humid and lake level was at least 1070 m a.s.l. until Mid Holocene. At this time the paleolake was expanded and flowed out northward possibly.

Paleoclimatic and socio-environmental dynamics in northwestern Arabia during the Holocene: wetland and dune archives in the AlUla oasis

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Oases are man-made environments which are adapted responses to hydro-climatic constraints in arid environments. They offer a unique opportunity to understand the interaction between agrarian, social and climatic dynamics as they record and provides sedimentary archives which are key to understand the causes of socio-environmental transformations and the adaptations of agricultural societies to these changes. Research conducted in northwestern Saudi Arabia reveals the paucity of our knowledge on these questions in this part of the peninsula, particularly after 3000 B.C., i.e. at the beginning of the Bronze Age.

The fluvial oasis of AlUla in Northwestern Saudi Arabia provides a unique research background following the development of archaeological and environmental research projects in this oasis since 2019. Located at the foot of the Harrat al-Uwayrid formation which separates the sandy deserts of northern Arabia (Hamra Desert) from the Red Sea, AlUla is characterized by the development of emblematic sites such as the Late Bronze Age site of Dadan, the Nabataean site of Hegra, and the old city of AlUla. While providing information on settlement dynamics, recent research has also revealed the development of agro-pastoral activities since the Neolithic and hydro-agricultural development from the Late Bronze Age onwards.

In order to better understand the environmental and climatic background in which the oasis developed, alluvial, eolian and playa sedimentary archives were studied in the AlUla watershed. Geomorphic mapping, core drilling, stratigraphic description of exposed sedimentary archives were conducted in the field and samples collected for sedimentological analyses (grain-size, geochemistry, Magnetic Susceptibility) and chronology (14C and OSL).

Our results highlight a long-term tendency towards aridification since the second part of the Holocene as well as short-term climatic oscillations. The confrontation of our results with available archaeological and environmental data available at the regional scale allow us to draw first hypothesis on the impact of the climate on the local societies for the last 10 millennia.

Human-landscape interaction through time in prehistoric and ancient Sicily: a GIS based approach

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Sicily, the main Island in the Mediterranean Sea, is an interesting open-air laboratory where experiment different tecniques and approaches in order to study the human-landscape interaction at least over the last sixteen millennia. Data from historic, cartographic, aerial images and satelite archives, and the availability of Digital Elevation Model and Digital Terrain Model helps in the interpretation of data from archaeological research and in the contextualization of human activities within the peculiar territory of the Island.

A GIS-based approach combining different kind of raster data-source with georeferenced archeological and paleoenvironmental sites of interest has been devoted to the study of the human-landscape interaction through time. In particular, the attention has been focused on Slope and Aspect computation, Viewshed Analysis, Least Cost Analysis in order to deal with settlement strategies, in a diachronic perspective, on a regional scale.

Hilly and mountainous territories have played a central role in the settlement strategies offering peculiar resoureces: natural refugia (dolines, caves and rockshelters in karst environments), strategic visual control points and a fast and direct mobility system, with paths exploited at least over the last ten millennia. Coastal landscapes, where human settlement have been concentrating during the whole Holocene, particularly after the Greek colonization, have been intensely exploited and partly modified by farming and herding activities. The ancient road system, besides, has shaped a new Island, creating new connections among (un)connected territories.

Quantifying human impact during industrialisation on the evolutionary trajectory of Vosgian streams (NE France): the value of documentary archives

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The anthropogenic pressure on European rivers has greatly intensified since the Industrial Revolution through channelisation, rectification, and building of dams and weirs. Against this background, focusing on the Vosges Mountains (NE France) is particularly relevant since it is a heavily populated low-mountain range whose hydrographic network was accordingly impacted by widespread human modifications. No less than ~5000 hydraulic structures (HS) mostly involving levees and weirs were built along and across the main streams draining the massif. Contrary to large rivers (e.g. the Rhine), the edification periods of these HS in smaller catchments remains largely unknown yet, thereby impeding a precise chronological reconstruction of the main phases of human pressure and environmental trajectories.

In this study, we aim to gain insight into the spatio-temporal anthropisation of three main streams draining the southern part of the Vosges, i.e. the Fecht, Vologne and Moselotte, and to evaluate their historical morphodynamic adjustments from the end of the 18th century onwards. We took advantage of the abundant paper archives, i.e. written reports, plans…, from the "*Ponts et Chaussées*" administration, which collected at the local scale every official request to build HS along and across streams from the 18th to the 20th century. Firstly, we characterised and mapped every weir and levee along the three studied streams to produce an updated database of the present distribution of HS. Secondly, we analysed the archives to date the construction (and in some cases deconstruction) of the HS. Finally, we reconstructed the diachronic evolution of the channel pattern, from an ancient topographical map (1866) and two orthophotos (1951, 2018). Our results allow a first quantification of human impacts: the construction year of present weirs across the Fecht, Moselotte and Vologne was dated to 12%, 31% and 56%, respectively. Most of them were probably built in the middle of the 19th century. Importantly, we also evidence a spatio-temporal correlation between the construction of HS and the simplification of the channel pattern. Although the use of historical documents has several limitations (e.g. loss, destruction, unavailability), we demonstrate that they are valuable archives that usefully complement field observations and investigations.

Modular geomorphological approaches along urban-rural gradient in the city of Rome (Italy)

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The urban environment is generally characterized by an urban-rural gradient where the anthropic impact decreases from the historic city center (where anthropogenic pressure is heavier) to the suburbs and peri-urban areas (where a greater presence of open spaces and green areas is affirming). In the Anthropocene, urbanization and correlated infrastructure building highly impact and sometimes completely obliterate natural landscapes. Although urban geomorphological mapping, modeling, and reconstructions are fundamental in understanding human-landscape interaction and associated geomorphological risk, human activity as a morphogenetic agent along the urban-rural gradient is not yet fully understood.

In the framework of the national geomorphological cartography project, our work presents interdisciplinary techniques used to reconstruct the transient landscape between natural and anthropogenic environments and the geomorphological histories of the city of Rome.

Case studies within a 600 km^2 area surrounding the Italian capital city will be presented, showing the modular approaches applied along the urban-rural gradient. In detail, a traditional geomorphological survey was applied in natural areas. Whereas, in modified to completely urbanized landscapes, the analysis of data covering the entire urbanization time, including archeological data, historical and recent topographic maps, and digital elevation models, were fundamental to detect the anthropic modifications on the natural landscape.

Geoarchaeology of the largest prehistoric mound in Europe: multidisciplinary investigations in the Hill of Udine (NE Italy)

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According to legend, the hill dominating the city of Udine (NE Italy) was built by Attila the Hun's soldiers in the 6^{th} century, but its natural or anthropogenic origin has been debated until now. In particular, in the last decades the researches mainly pointed to a tectonic origin of the relief as an uplifted remnant of glacial or fluvioglacial deposits of the Middle Pleistocene. The hill rises for about 30 m over the surrounding alluvial plain and its flat top hosts the palace built over the ruins of the castle destroyed by the earthquake of 1511 CE.
In the framework of a collaboration between Ministry of Culture, Municipality of Udine and University of Padova, five new stratigraphic cores were drilled in 2020-22 up to 40 m of depth from the hilltop and some new archaeological excavations on the hill and at its base were carried out. The geoarchaeological and other multidisciplinary analyses, supported by the comparison with the archaeological and ethnographic data, allow to demonstrate that the hill is an anthropogenic mound built in the final part of the Bronze Age and that the folklore transformed the ancestral memory of its origin into legend. The hill, which measures 30 m in height and over 400,000 m^3 in volume, had already these dimensions since the its first construction and, thus, it is the largest prehistoric mound in Europe. Paleopedologic, paleobotanic and geochronological investigations allow to reconstruct the environmental setting existing when the mound was built, evidencing some peculiar characteristics that favored the flourishing of the settlement in the area of Udine.
The mound consists of alternations of gravelly and soil lenses quarried in the surroundings and this excavation led to create a depression extending for almost 100,000 m^2 that was used as a water basin for supplying the settlement. This discovery reveals unprecedented skills in earth construction and territorial management, confirming the significant anthropogenic modifications of the environment during the Bronze Age.

Paleomagnetic and rock magnetic investigations of cave sediments in Lipiška Jama: insight into Classical Karst (SW Slovenia) evolution

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The Lipiška jama Cave at the south edge of the Kras Plateau (Slovenia) is a 1,400 m long, inclined to the SSW. It is recently functioning in epiphreatic and vadose regimes. Three allogenic sedimentary sections, each 2 to 3 m thick, deposited in three different levels of the same cave passage (i.e. Kozinski rov), were sampled (bottom, middle, top). With the exception of the bottom level section, which was disturbed by slides and slumps, the other two sections were sampled using high-resolution method. For magnetomineralogical characterization of the sediments rock magnetic methods such as acquisition of isothermal remanent magnetization, S-ratio, anisotropy of magnetic susceptibility (AMS), etc., were used. Magnetic susceptibility shows a wide variation of values in all three sections. A low coercivity mineral (e. g. magnetite) is identified as the main carrier of magnetization. The AMS shows dominantly oblate fabric, which corresponds to fine-grain sedimentation. Alternating field demagnetization was applied to determine characteristic remanent magnetization (ChRM). Primary magnetization, and the presence of both normal (N) and reverse (R) polarity samples, were determined. The section in the bottom level of the cave passage, which was extensively influenced by post-depositional features, displays a chaotic distribution of the ChRM components. The section in the middle level of the cave passage reveals R and N polarity zone within the allogenic sediment with a nearly antipodal position of their mean directions, as well as basal flowstone with R polarity. The highest positioned section reveals mainly R polarity and occasionally N polarity samples. Although the homogenous non-laminated clay forms this sedimentary sequence, AMS parameters suggest some samples suspected of slumps behaviour. The presence of R polarity zones in two studied sections in the Lipiška jama suggests an age at least within the Matuyama Chron. Correlation with other sections in the area will help the understanding the evolution of the Classical Karst.

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Paleo- and rock-magnetic investigations from the upper unconsolidated sedimentary sequence of a drill core (20HCL04) from the Jeokjung-Chogye basin (impact crater), Korea: Towards chronostratigraphic constraints

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The Jeokjung-Chogye basin situated in Hapcheon County, southeastern Korean Peninsula, is presumed as a Quaternary meteorite impact crater. In the impact crater basin, we retrieved a drill sediment core called '20HCL04', which was the azimuthally non-oriented drill core, with a drilling depth up to 66.0 m. From high-resolution discrete samples (collectively, n= 747) from the unconsolidated sedimentary sequence at the 14.0–42.0 m depth interval, we has conducted paleo- and rock-magnetic investigations, which aims to test the usability for obtaining chronological constraints for the core. Progressive alternating field demagnetization (AFD) behavior of natural remanent magnetization (NRM), and results from strong-field high-temperature thermomagnetic analysis and the high-temperature three-axis isothermal remanence (IRM) Lowrie test indicate the existence of two (or more) low-coercivity magnetic minerals as major remanence carriers, probably magnetite and greigite, and notably allow to confirm predominant greigite contribution at many parts of the investigated interval. Based on the initial magnetic susceptibility values and characteristic remanence (ChRM) determinations from the NRM AFD results, we preliminarily construct and evaluate a magnetostratigraphic record consisting of ChRM inclinations and tentative relative paleointensity (RPI) values for the core, conservatively excluding those data that are potentially regarded as derived from greigite authigenesis. The constructed magnetostratigraphy allows us to recognize that the whole analyzed interval corresponds to a single persistent normal-polarity chron, in which there are multiple, large-amplitude directional swings associated with respective remarkable RPI lowering. This finding has the potential to provide us key tie-points of age-depth relationship for ultimately reconstructing the best reliable, accurate, high-resolution chronology for the core. We, accordingly, believe that further paleomagnetic researches will be necessary in future.

Paleomagnetic and rock magnetic analyses on sedimentary cores from Ross Sea, Antarctica (CHIMERA project, PNRA)

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A paleomagnetic and rock magnetic investigation was conducted in the framework of the multi-disciplinary project CHIMERA (CryptotepHra In Marine sEquences of the Ross Sea, Antarctica: implications and potential applications) funded by the Programma Nazionale di Ricerche in Antartide (PNRA). Data was acquired by taking 1-cm spacing magnetic measurements from sediment cores collected in the continental shelf basins of the Ross Sea (Antarctica) in the frame of previous PNRA research project. The analyzed sediment shows good paleomagnetic properties which allow the reconstruction of well-defined characteristics remanent magnetization (ChRM) showing some inclination features that can be related to the already know excursion of the past geomagnetic field. Moreover, the relative paleointensity (RPI) curves constructed for the sedimentary successions, coupled with tephrostratigraphic and biostratigraphic studies, provide high resolution chronological constraints for age calibration. Finally, the rock magnetic parameters trend throughout the cores gives us information useful for the paleoenvironmental reconstruction linked to the advancement-retreat phases of the ice shelf in this region in the last climatic cycle.

Integrating 40Ar/39Ar, paleomagnetic and geochemical data to evaluate the geomorphic response to water-lava interaction in Swan Valley, Idaho, USA

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Volcanism on the Earth's surface plays a major role in the evolution of the landscape. The timing and progression of river systems that have been diverted by lava flows can be examined through high precision geochronology of the lavas. The Snake River (Idaho, USA) was dammed multiple times, and in several locations, by voluminous basaltic lavas, resulting in the reorientation of the Snake River. Understanding the origins and ages of these lavas are important to understanding the development of the present-day landscape. In eastern Idaho, the Swan Valley graben preserves a record of water-lava interaction through the development of a lava dam. Intercalated subaerial lavas, pillow lavas, and hyaloclastite suggest prolonged interaction between volcanism and standing water. Previous workers hypothesized that the lava dam generated an extensive, albeit short-lived, paleo-lake that existed until the lava dam was breached, causing the Snake River to divert its course into its present-day canyon. In this work, we examine the geochemistry and paleomagnetism of the basalt lavas in the graben to determine an eruptive history, estimate the volume and fill rate for the paleo-lake, and calculate incision rates of the diverted Snake River through Quaternary basalts. Our results show that multiple Quaternary lavas flowed within the graben, culminating in the 904 ka eruption that produced the hyaloclastite dam. We further propose that the paleo-lake was less extensive than previously described and instead shallow marshy, wetland conditions existed to produce the hydrovolcanic deposits. Finally, for the period between 900 and 60 ka, we determine an incision rate of 0.014 cm/yr for the Snake River to carve through a succession of Quaternary basalts, which is consistent with, albeit slightly higher than, rates calculated from 60 ka to present.

Major dune construction during Younger Dryers along the Kankakee River Valley, Midwest USA

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Sand dunes and sand sheets are located along the south side of Kankakee River Valley in Illinois and Indiana, which overlie glaciofluvial outwash, lake sediments, and bedrock of Middle Paleozoic shales and carbonates. Dunes are prominent feature of the landscape, and most dunes are 4.5 to 8 meters high, and some reach 50 feet. Due to the lack of natural exposure and roadcuts, three dunes were sampled by hand augering for optically stimulated luminescence (OSL) dating. Ground penetrating radar (GPR) surveys were conducted for a better understanding of the stratigraphy where exposures are not available. Results show that all three sites contain ages within the Younger Dryas chronozone (11.5-12.8 ka). More importantly, we found that at site 1 there are about 8 meters of eolian sand yielded 5 ages within the Younger Dryas chronozone. Although the large error bar of singular individual OSL age (about 6-9%, about 0.8-1.2 ka) usually does not allow for the determination of a specific climatic event, multiple ages from multiple sites of these dunes and striking thickness in this study all fall into the range of Younger Dryas chronozone. Thus, we believe that the rapid climatic changes before, during and after Younger Dryas play key roles in the dune construction here in the Kankakee River Valley. These changes of the ages are consistent with GPR image and lithology changes observed in the field.

A revised Greenland ice-core chronology for the last 3800 years: the GICC21

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Ice-core timescales are vital for the understanding of past climate; hence they should be updated whenever significant amounts of new data become available. Here, the Greenland ice-core chronology GICC05 was revised for the last 3835 years by synchronizing six deep ice cores and three shallow ice cores from the central Greenland ice sheet.

The new timescale is younger than GICC05 by about 13 years at 3835 years ago. The most recent 800 years are largely unaffected by the revision. Between 800 and 2000 years ago, the offset between timescales increases steadily, with the steepest offset occurring between 800 and 1100 years ago.

By analysis of the common variations in cosmogenic radionuclides, the new ice-core timescale is found to be in alignment with the IntCal20 curve.

Do standard treatment and storage techniques contaminate environmental archaeological samples and affect the reliability of radiocarbon dating

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There is concern in the archaeological community to reduce the use of chemicals that contain carbon compounds in plant and insect sample processing and storage. This is to avoid contamination of samples that are otherwise valuable for ^{14}C measurement. These chemicals (e.g. paraffin, ethanol, glycerine) can introduce carbon that has a different ^{14}C age to that of the sample into the sample matrix. If this carbon cannot be removed during pretreatment, it will compromise the accuracy of a sample^{14}C measurement. Yet, these chemicals have significant value for processing and storage, significantly reducing sample preparation time and enabling archive samples to be stored and studied at a later date. Whilst individual projects have both successfully dated material after periods of storage and removed other preservatives, there has been no systematic chemical analysis of this particular problem.

We present results from a series of experiments designed to address this problem. The experiments have been undertaken on modern-day seeds and beetles which have a ^{14}C date in equilibrium with current atmospheric levels. Samples that have been paraffin-floated and stored in ethanol for c. 10 years have been compared with recently resampled material from identical locations that have been subjected to a range of controlled treatment and storage protocols. Fourier transform infrared (FTIR) spectroscopy will be undertaken on these samples and on blanks of each relevant chemical, to determine whether traces of processing chemicals are retained in the sample matrix. In this way we can fully characterise the spectra and monitor the removal of processing chemicals.

This project has important implications for the workflows used in environmental archaeology. If researchers can be confident that paraffin-floated and variously stored samples are not contaminated and can still be ^{14}C dated it will significantly increase the efficiency of sample processing.

Palaeoclimatic and morphodynamic interpretation of periglacial landforms in Jotunheimen (South Norway) applying Schmidt-hammer exposure-age dating (SHD)

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The potential of periglacial landforms in the context of palaeoclimatic interpretation is based on their connection to climate-driven permafrost conditions for both their development and subsequent activity. Its utilisation to extract certain palaeoclimatic signals is, however, complicated by the challenge to obtain reliable numerical age date for these landforms. Many represent rather transitional or diachronous processes of certain duration than clearly defined single events. Additionally, postdepositional disturbance by frost-related processes is quite common.

With the resulting sample sizes required for obtaining representative data for boulder-dominated periglacial landforms, an application of cosmogenic radionuclide dating (CRN) seems hardly viable both financially and timewise. The calibrated-age dating technique of Schmidt-hammer exposure-age dating (SHD) has, by contrast, been successfully utilised for this purpose during the past decade. If independent (numerical) age data allows to establish local or regional age-calibration curves, SHD offers the fundamental advantage of obtaining large sample sizes (hundreds or even thousands of boulders) to overcome the abovementioned limitations of CRN.

The potential of SHD will be highlighted by a study of patterned ground and related solifluction features on Juvflye in Jotunheimen (South Norway). Application of a reliable local SHD age-calibration curve revealed that all studied patterned ground and solifluction features seem to have become stabilised and inactive prior or around the onset of the Holocene Thermal Maximum. With their development likely commencing after local deglaciation around the Preboreal Oscillation their morphodynamic activity was restricted to the Early Holocene despite that fact that in both higher and middle altitude the features have continuously been underlain by permafrost during the entire Holocene until present. And whereas an altitudinal gradient with slightly longer activity at higher altitude was detected with sorted circles, no similar signal was detected for sorted stripes and solifluction features.

Summarising, the SHD stabilisation ages obtained challenge the general application of large patterned ground features as palaeoclimatic indicators for permafrost. From a morphodynamic point of view permafrost *per se* cannot be the sole factor for efficient formation of patterned ground. Factors such as soil moisture, availability of suitable substrate etc. need to be taken into account.

Evidence of mass mortality of the long-lived bivalve Mercenaria stimpsoni caused by a catastrophic tsunami

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Tsunamis are huge disasters that can significantly damage benthic organisms and the sea-bottom environment in coastal areas. It is of great ecological importance to understand how benthic ecosystems respond to such destructive forces and how individual species are affected. Investigating the effect of such disasters on animals that are seldom caught alive is particularly difficult. Bivalve mollusks are especially suitable for investigating how a tsunami affects coastal benthic species because they preserve an environmental record in their shells that can be extended back in time by crossdating the records of multiple individuals. Here we studied dead shells of *Mercenaria stimpsoni*, a long-lived clam, and precisely determined the time of death by using nuclear bomb–induced radiocarbon (bomb-14C) and by counting annual growth increments (sclerochlonology). First, a quasi-continuous, regional bomb-14C record was created by analyzing the shells of 6 live-caught *M. stimpsoni* individuals. Then 27 dead shells collected from the seafloor of Funakoshi Bay were 14C-dated and analyzed. The results showed that the huge tsunami that struck northeastern Japan on 11 March 2011 caused mass mortality of this bivalve in Funakoshi Bay. Nine of the 27 clams died during the March 2011 tsunami, probably by starvation after burial by tsunami deposits or exposure above the seafloor as a result of sediment liquefaction during the earthquake. The dating method used in this study can help us understand how long-lived marine organisms with low population density are affected by huge natural disasters such as a tsunami.

Holocene marine radiocarbon reservoir effect derived from C-14 and U-Th dating of corals for the Penghu Island, Taiwan

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Studying the regional marine reservoir effect and its change over time is essential for precise radiocarbon dating of marine samples and the study of past ocean-current information. However, there are only a few marine reservoir ages (R) and marine reservoir corrections (ΔR) available from pre-bomb shells collected at northeastern Taiwan during the 19th century. Here we provide the first report of R for Penghu Island (23°34' N, 119°34' E) in the Taiwan Strait for the past 6700 years, obtained from XRD examination, and ^{14}C and U-Th analyses of shallow-water corals. The R varied from 200 to 420 ^{14}C years during the past 5000 years, and higher Rs, up to ~600 ^{14}C years, were observed between 5700 and 6700 cal BP. The weighted mean ΔR value in the past 5000 years is -154±51 years based on MARINE20, similar to the pre-bomb values from the same site and the Ryukyu Islands, but much lower than the previous shell data of northeastern Taiwan (-78±46 years, recalculated also based on MARINE20). According to the R variation, our results agree with previous studies from the Great Barrier Reef in the southern Pacific Ocean and the South China Sea (center at 15°N), indicating that the ocean current with depleted ^{14}C values during the mid-Holocene extended from the equatorial Pacific up to the Taiwan Strait, and likely to the further north of the continental shelf. More data collection along the Taiwan coast is in progress.

Palaeoearthquake history revealed by a combined detrital zircon U-Pb and OSL ages: a case study at Inbo site on the Southern Yangsan Fault, Korea

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Earthquake rupture can induce changes in the landform and depositional environment. Such modification in topography and depositional setting makes changes source to sink system of sediment. If the timing of topographical changes is strictly constrained, the period of paleoearthquakes can be tracked. Here, we conducted OSL with detrital zircon U-Pb age datings on the unconsolidated units of the Inbo trench excavations in the Yangsan Fault, the southeastern part of the Korean peninsula reported by Cheon et al. (2020). In this study, the depositional ages for four units of the Inbo trench excavations are identified from far earlier than 70 ka to after 29 ka by the OSL ages, and three units were rapidly deposited at ca. 70 ka. The most recent and the penultimate earthquakes are determined after 29 ka and between ca. 70 to 50 ka, respectively. Clustered three units having depositional ages of ca. 70 ka show twice abrupt changes in U-Pb ages of detrital zircon along with the replacement of the sedimentation setting from fluvial and sag-pond to slope sediments. Since such dramatic changes in U-Pb ages of detrital zircon imply at least twice paleoearthquakes events, the Inbo site means that at least four paleoearthquakes have occurred. This study suggests that the period of additional fault activity can be identified using multiple techniques obtained by OSL and detrital zircon U-Pb age in paleoearthquake studies.

Cheon, Y. et al., 2020, Late Quaternary transpressional earthquakes on a long-lived intraplate fault: A case study of the Southern Yangsan Fault, SE Korea. Quaternary International, 553, 132-143.

Application of burial dating using multiple cosmogenic nuclides in Korea: from Quaternary geology to Geoarchaeology

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Deeply buried sediment and artifacts can be dated using multiple cosmogenic nuclides for timescales up to 5 million years through the radioactive decay of these two nuclides. Various research has proven that in situ cosmogenic nuclides can be successfully used in various scientific fields, including Quaternary geology, geomorphology, geoarchaeology, and paleoseismology. Burial dating provides a reliable tool for figuring out the ages of key layers when other dating methods are sometimes unavailable. Since the method has been successfully applied to a number of those scientific fields, this research introduces the application cases and results of burial dating using Multiple Cosmogenic Nuclides (With the proven 10Be/26Al nuclide pair, quartz-bearing material can be numerically dated from about 100 ka to 5 Ma) through samples obtained from drilling cores and trenches in Korea.

Intense Holocene eruptions and landslide activity at Tacaná Volcanic Complex (Mexico) constrained by 36Cl surface exposure dating, lichenometry and dendrochronology

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Usual methods are unfortunately not suitable for accurately date Holocene deposits and landforms from active volcanoes. An example is Tacaná Volcanic Complex (TVC), situated in the State of Chiapas in southern Mexico, and the San Marcos Department in Guatemala. The complex is formed by four main structures: Chichuj, Tacaná, and San Antonio volcanoes and the Ardillas dome. Here, we have undated lava domes (summital and Ardillas), lava (Andesitic) and a horseshoe shaped crater's cliff and we determined their age using surface exposure dating with in situ-produced cosmogenic ^{36}Cl, lichenometry and dendrochronology. The ^{36}Cl exposure ages (9.3 ± 1.9 ka; 8.9 ± 0.9 ka; 8.6 ± 1.7 ka) of the summit domes suggest that they were emplaced during Early Holocene whereas the southern part of collapsed crater yielded ages ranging from 5.3 ± 0.6 to 7.0 ± 0.8 ka. The ^{36}Cl exposure age of an andesitic lava (0.4 ± 0.1 ka), emplaced to the SW of Tacaná, agrees with the chronology provided by lichenometry and dendrochronology (> 347 yr). These ages could represent a gravitational collapse event associated with phreatic explosions vented close to a scar collapse.
However, the ^{36}Cl exposure ages derived from the southeastern edge of the Ardillas lava dome (0.3 ± 0.1 ka) did not represent its emplacement age because the dome is covered by 760 ± 30 yr BP (^{14}C) old pyroclastic deposits. Therefore, the rock sampled at the Ardillas dome may represent the remains of a landslide scar and associated rock-avalanche. Overall the combination of in situ-produced cosmogenic ^{36}Cl, lichenometry and dendrochronology constitute a solid approach to determine the age of undated volcanic landforms contributing to the reconstruction of the volcanic history.

36Cl surface exposure dating reveals the youngest eruptions in Sierra de Chichinautzin to the South of Mexico City

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Conventional methods are unable to accurately date many Holocene landforms. Knowing the Holocene volcanic history is however necessary to mitigate hazards and related risks, which is particularly relevant in the case of active volcanic fields lying at the periphery of highly populated areas. An example is the Sierra Chichinautzin, located south of Mexico City where several Holocene volcanoes have been dated using radiocarbon. Based on this data, the youngest edifice of this monogenetic field is Xitle volcano (316-430 cal AD) but the age of other young volcanoes remains poorly constrained, calling for the use of other methods.
In this study, we applied *in situ*-produced cosmogenic ^{36}Cl dating to constrain the age of Texcal and Chichinautzin volcanoes whose well-preserved morphologies suggest similar to younger ages than Xitle. Texcal was previously mistaken as part of the older Guespalapa volcano and radiocarbon ages for these volcanoes are few and inconclusive. The results show that lava from Texcal volcano, which forms a 21 km long lava flow fed by a row of spatter cones and ramparts, yields an age of 1028 ± 324 years. On the other hand, lava from Chichinautzin volcano, which forms a broad shield capped by a small cone, yields an age of 1059 ± 333 years. Therefore, both volcanic structures are younger than Xitle, being the youngest eruptions reported in Sierra de Chichinautzin. Hence, *in situ*-produced cosmogenic ^{36}Cl constitutes a solid approach to define the age of Holocene volcanic landforms allowing to revise and significantly improve the reconstruction of the volcanic history.

Soil organic carbon dating of paleosoils of alluvial fans in a blown sand area (Nyírség, Hungary)

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The most widely-used dating techniques in quaternary research are the radiocarbon and optically stimulated luminescence (OSL) dating methods. In some environments, the investigated sediments do not contain enough material for radiocarbon dating. In these cases, radiocarbon dating of bulk sediment may be used as a last resort.

The major aim of the present study, was to determine the reliability and limitations of the different fractions of the soil organic carbon (SOC) C-14 ages in the Nyírség blown-sand study area, in Hungary. Therefore, the low- and high-temperature combustions of SOC (LT-SOC and HT-SOC) C-14 age of fossil soils were compared with the charcoal ages from the same fossil soil layer, and their (LT-SOC, HT-SOC and charcoal) age reliability was verified independently by applying OSL to the quartz fraction of the sediment samples.

From the Nyírség blown sand area, 8 stabilised sand dunes were chosen for sampling. These dunes contain clearly observable fossil soil layers. For Accelerator Mass Spectrometry radiocarbon measurements, we collected soil and charcoal samples from the same fossil soil horizon at 8 difference locations. From 5 locations, OSL samples were also collected 50 cm below and above the investigated fossil soils to control the radiocarbon results.

The radiocarbon data show variable agreement with OSL ages. Charcoal fragments were collected from some of the best material for radiocarbon dating and their ages are in agreement with the LT and HT-SOC C-14 ages and OSL data. The radiocarbon age LT-SOC gives a reliable, credible ages, which were confirmed by independent OSL measurements. If buried soils do not contain any other macroscopic remnants for radiocarbon dating, the LT-SOC C-14 ages can be used, in the case of the Nyírség study area. The LT-SOC, which is the younger fraction of the soil organic carbon, may be considered to represent the burial time of the fossil soil layer. The HT-SOC radiocarbon ages are sometimes unrealistically older than expected and cannot be considered to be reliable.

Constraining the chronology of Quaternary fluvial sediments in the Pannonian Basin.

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The correlation of terrestrial deposits with the marine oxygen isotope record is often challenging due to the lack of continuous stratigraphic sequences and material for radiometric dating. The Great Hungarian Plain contains large basins with a thick alluvial succession, almost 500 m in depth, providing a long-term record of Quaternary terrestrial deposits. Five fully cored boreholes have been collected from the Körös and Jászság basins and Makó Trough. Two paleomagnetically-dated boreholes from the Körös Basin were correlated with the other three boreholes by the magnetic susceptibility of the sediments and the first and last appearance of the freshwater gastropod *Viviparus boeckhi*. The cyclic nature of the magnetic susceptibility throughout the stratigraphy, in relation with the early postglacial degradation of mountain permafrost, provides a mechanism for correlation between the boreholes. This also enables correlation to the marine oxygen isotope record.

The chronology established by this approach was tested using amino acid geochronology. Calcitic opercula from bithyniid freshwater snails were analysed using the intra-crystalline protein decomposition (IcPD) approach to build a relative chronology across the five boreholes. The operculum specimens were obtained from the Krolopp Malacological Collection. This was the first time that IcPD analysis of opercula was used to develop a time signal for cores of depths greater than 65 m; despite concerns that the degradation reactions might be impacted by the geothermal gradient, results from the IcPD analysis support the chronology developed using magnetic susceptibility stratigraphy. This demonstrates the potential for the use of amino acid geochronology for correlating deep cores throughout the entire Quaternary period.

Pretreatment of sorted pollen grains for radiocarbon dating

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Sedimentary deposits can provide a challenge for radiocarbon dating because the ultimate sources of the carbon contained within bulk sediment from each horizon are often many and unknown. Isolating and dating one component of the sediment allows for a better understanding of the carbon source and, thus, a better interpretation of the measured age but is technically difficult and reduces the amount of carbon available for analysis.

Because of their wide-geographic distribution, relatively high abundance, resistance to diagenesis and terrestrial origin, pollen grains are an ideal material for the accurate radiocarbon dating of sedimentary horizons. Moreover, sedimentary horizons are frequently examined for their pollen composition. The recent development of an extraction method to isolate fossil pollen grains from sediment using flow cytometry (Yamada et al., 2021) provides an opportunity for the exploitation of pollen for radiocarbon dating (Omori et al., 2022).

Ritsumeikan University and University of Oxford Radiocarbon Accelerator Unit now offer a joint service to isolate and radiocarbon date pollen grains extracted from bulk sediment. This poster describes the pretreatment of the sorted grains produced by Ritsumeikan University necessary for accurate dating.

Omori T., Yamada K., Kitaba I., Hori T., Nakagawa T. (2022) Reliable radiocarbon dating of fossil pollen grains: it is truly possible. *Quaternary Geochronology*,in submission.

Yamada K., Omori T., Kitaba I., Hori T. and Nakagawa T. (2021) Extraction method for fossil pollen grains using a cell sorter suitable for routine 14C dating. *Quaternary Science Reviews* **272**, 107236. https://doi.org/10.1016/j.quascirev.2021.107236

Comparing and optimising Bayesian age-depth modelling approaches from European lacustrine varved records through the Holocene.

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Lacustrine varved sequences provide some of the most important palaeoclimatic archives through the Holocene, as they offer records of past climate change at an annual to seasonal resolution.

Varve chronologies provide independent timescales based upon annual layer counting, but robust age-depth models are required to verify and anchor varve chronologies, and temporally analyse and compare floating records on sub-centennial calendar timescales. This is most readily achieved by constructing age-depth models using Bayesian statistical approaches. There are now a range of age model packages available to palaeoclimatic researchers, which utilise different approaches to produce sedimentary age-depth models, but there is no standardised approach in which to construct age models for varved records. Typically, varved chronologies are anchored to calendar timescales using a single package and a single modelling setup, with no justification on why the chosen model was selected. This approach inevitably leads to sub-optimal accuracy and precision. New coding packages including 'geochronR' and 'LANDO' provide the potential to efficiently compare and combine different age-depth modelling approaches and iterations for varved records, to identify the optimum approaches to construct the best calendar chronologies for different palaeo-records.

This presentation will discuss comparisons of different age-depth modelling approaches (e.g. 'rBacon', 'Oxcal','Bchron') on Holocene varved records, including the continuously laminated Diss Mere sequence in southern England. The aim of these comparisons is to identify the best age modelling approaches to produce precise calendar age-depth models from different sources of chronological information (e.g. varve layer counting, tephras and radiocarbon dates). The presentation will then summarise some of the limitations of using only a single age model, and why a more systematic approach is required to optimise age model outputs for Holocene varved records.

Viscous remanent magnetization dating of the subsurface late Pleistocene fluvial gravel beds beneath the Tokyo Lowland, Japan

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Fluvial gravel deposits filling late Pleistocene incised-valleys beneath coast planes of Japan are significant key marker beds to correlate strata laterally, reconstruct basin evolutions, and evaluate active tectonics. However, it is very difficult to date the fluvial gravel beds due to the lack of organic material, microfossils and tephra beds. Therefore, many of these depositional ages and spatial-temporal variations of the sediment distribution are unclear in many cases. In this study, we attempted to constrain the depositional age of lowstand fluvial gravel beds in the Tokyo Lowland, by a viscous remanent magnetization (VRM) dating approach, which has been applied to estimate the reworking age of massive boulders by geological hazards.

Igneous pebbles were collected from all-core boring samples obtained from the Tokyo Lowland. The pebbles were cut into specimens with approximately 1 cm^3. To infer magnetic minerals in specimens and those magnetic domains, we conducted magnetic measurements including hysteresis curves, first order reversal curves (FORCs), thermomagnetic (Js-T) curves, stepwise isothermal remanent magnetization (IRM) acquisition experiments, and viscous decay experiments of IRM at temperatures. Natural remanent magnetizations (NRMs) were measured during progressive thermal demagnetization experiments upto 600 ˚C in 5–20 ˚C-increments.

The Js-T curve (Curie temperature), the IRM acquisition curve (magnetic coercivity spectra), and FORC diagram (magnetic domain distribution) exhibit that examined specimens mainly contain titanomagnetite and/or poor-Ti titanomagnetite with vortex state and multi-domain (MD) sizes. In a ThD result, a low-temperature component in an NRM, which is probably a VRM, was clearly distinguished from a high-temperature primary component at ca 230˚C. Based on the result of the viscous decay experiment of IRM, we determined a parameter to calibrate the effect of vortex state and MD size titanomagnetites to the age estimation. Using the demagnetization temperature of the VRM, calibration parameter, and an observed temperature at 50 m deep in the Tokyo Lowland, the depositional age of the pebble was calculated as late MIS 2, which is consistent with inferred age based on C-14 dating obtained from mud beds above and below the fluvial gravel bed. The accuracy of age constraints will be improved by increasing the number of specimens.

A new cosmogenic nuclide dating laboratory in CENIEH, Spain

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Centro Nacional de Investigación sobre la Evolución Humana (or National Research Centre on Human Evolution, CENIEH) is located in Burgos, northern Spain. The centre is dedicated to human evolution research worldwide, including Atapuerca, a world heritage archaeological site where the oldest human fossil in Europe to date have been discovered. To support the needs of characterising geological and sedimentological context of archaeological sites, the institute also features a wide range of geological analysis (e.g., Laser diffraction grain size analyser, XRD, XRF, Raman Spectroscopy, SEM, Micro CT, Digital mapping and 3D analysis) and geochronology laboratories (including palaeomagnetism, OSL, ESR and U-series). In 2020, a new cosmogenic nuclide dating research line has initiated to strengthen the existing geochronological capabilities in the centre, particularly, at timescales of early-mid Pleistocene and beyond. To date, we have established a procedure for routine quartz separation and ^{10}Be-^{26}Al extraction. Current projects include ^{10}Be-^{26}Al burial/isochron dating of cave deposits, fluvial terraces and artefacts in the context of archaeological and landscape evolution research. In this paper, we present a general setup of the laboratory, its capacity and current projects as well as future prospective.

The Late Holocene climate variability and their impact on cultural dynamics in the central India

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The understanding of long-term climate variability may provide valuable perspective on possible response of human societies to modern climate changes. The present study, based on the geochemical and sedimentological analyses on well dated (using AMS 14 C and optically stimulated luminescence-OSL dates) alluvial sediments from Sina River (in Maharashtra, central India) provides a detailed understanding of complex interplay between climate and cultural dynamics during the Late Holocene. The radiocarbon dates of the organic residues from the potsherds represents the Medieval period (~1600 to 950 cal yr BP), whereas the OSL sample shows the age of ~7.5±0.4 ka. Further, several cultural objects (e.g., potsherds, shell bangles, and copper artefacts) available at the site were also investigated in order to understand the extent of human activity in the region. The temporal changes in the proxies along with the abundance of cultural materials in the fluvial section during the medieval period suggest that the human population attempted to adapt against the fluctuating climate conditions. The regional comparison of geo-archaeological data sets shows that the pronounced weakening of the monsoonal rainfall during the Late Holocene coincides with the disruption, migration and resettlement of the indigenous societies, deciphering the possible impact of climate on human settlement.

Extending 40Ar/39Ar geochronology of clinopyroxene into the Quaternary

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Clinopyroxene is a common phenocryst phase in mafic to intermediate composition volcanic and plutonic rocks. It is highly resistant to alteration compared to other co-existing mafic phenocrysts such as plagioclase. Several recent studies have shown that clinopyroxene can now be precisely $^{40}Ar/^{39}Ar$ dated using a new generation of multi-collector noble gas mass spectrometers. Thus far, $^{40}Ar/^{39}Ar$ dating of clinopyroxene has primarily been conducted on Neoproterozoic to Jurassic dolerites as well as mid-Cretaceous to Miocene submarine basalts. To assess the viability of $^{40}Ar/^{39}Ar$ dating clinopyroxene at the youngest end of the geologic timescale, incremental heating experiments were performed on tens of milligrams of inclusion-free clinopyroxene from a variety of mafic lithologies and tectonic settings (subaerial arc basalts, gabbros, andesites, submarine basalts from mantle plumes), all of which are younger than 34 Ma. Most samples produced relatively precise plateau ages including several subaerial basalts to andesites that gave plateau ages ranging from 2.5 to 0.6 Ma. All data are indistinguishable from new and/or published $^{40}Ar/^{39}Ar$ and U-Pb ages on other minerals within these samples, which demonstrates that clinopyroxene can be utilized to obtain accurate and precise $^{40}Ar/^{39}Ar$ ages for Quaternary mafic to intermediate volcanic rocks.

Tephra compositional data: are we doing it right?

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Tephrochronology has become a powerful chronological tool that enables precise dating and correlation of palaeoclimate reconstructions. Tephra horizons preserved in natural archives act as common time markers and anchor points in age models. Using tephras for such purposes relies upon confident identifications based on the geographic and stratigraphic contexts combined with the morphology and the geochemistry of the tephra glass shards. The global tephra community continuously collects compositional data of new tephra findings, which further increases the complexity of this field of study (for example by introducing new candidates for correlation of tephras once thought to be unique).

Analysis of a tephra sample's glass geochemistry is commonly performed by electron probe microanalyser and reported as major-oxide weight percentages (as expressed by the instrument and/or as volatile-free normalised percentages). These results are then explored by the tephrochronologist and compared to datasets of previously reported findings to find candidates for identification by correlation. While this identification method has worked well in most cases, it is sometimes difficult to distinguish between tephras with overlapping geochemistries, where multiple candidates are viable. The likelihood of this scenario happening increases as new data are reported.

Statistical approaches such as principal component or discriminant function analysis have been used to differentiate sample populations and find statistically motivated identifications. However, the validity of these methods often requires certain assumptions not to be violated (e.g., data should not be collinear). Unfortunately, compositional data suffers from the constant-sum constraint—an issue which is rarely explicitly considered—and must be converted by log-ratio transformations for specific statistical analyses to function correctly. As there is no consensus on a tephra compositional data curation procedure that includes log-ratio transformations, we have explored several options to arrive at a formal recommendation for such a procedure.

Schmidt-hammer exposure-age dating (SHD) of glacial landforms in the Western Taurus Mountains, SW Turkey

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Schmidt hammer exposure-age dating (SHD) is a cheap and practical relative dating technique that measures the time of exposure of surficial rocks to atmospheric conditions. The Schmidt hammer has been used in a variety of geomorphological studies, including determining the rate of weathering, measuring rock hardness, and even assessing the relative age of landforms. Several landscapes can be studied using the SHD method, such as moraine deposits, fault scarps, rock glaciers, mass movements, and coastal elevations. Combined with terrestrial cosmogenic nuclide dating (TCND), the SHD was used in the first trial in the mid-2000s. Since the 2010s, these studies have gained in popularity. In this study, for the first time, the SHD method was employed in Turkey. The study took place in the Western Taurus Mountains in southwestern Turkey. In this region, over 200 cosmogenic surface exposure-ages have been obtained. SHD, as a fast and inexpensive means of dating, some undated locations could be studied by using the existing cosmogenic surface exposure-age data as age control points. Thus, the Western Taurus Mountains can be assigned a more comprehensive glacial chronology. In this study, the first outputs of the measurements with the Schmidt hammer performed on 137 moraine blocks and 2 bedrock surfaces bearing the traces of Quaternary glaciations in the Western Taurus will be presented.
This study was funded by the Scientific Research Projects Coordination Unit (BAP) of the Istanbul Technical University (Project ID: MDK-2022-43674).

Revised marine reservoir offset values (ΔR) for molluscs and marine mammals: Arctic North America and the Barents Sea–Svalbard region

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Using appropriate marine-terrestrial offset values (ΔR) when calibrating marine radiocarbon dates underpins accurate chronologies necessary for comparisons between environments, regions, and across different geochronological methods. However, ΔR values are strictly valid for the specific calibration curve that their calculation is based on. Here we summarize recently published revised ΔR values for the Marine20 calibration curve from two Arctic-Atlantic ocean gateways, the Canadian Arctic Archipelago (CAA) and the Barents Sea-Svalbard region. Our calculations are based on previously-published ^{14}C dates on pre-bomb live-collected marine molluscs and cetaceans, and bowhead whale-driftwood age comparisons from the same glacio-isostatically uplifted shorelines.

For the CAA, molluscan-based ΔR terms are: Chukchi/Beaufort sea coasts, 265 ± 116 ^{14}C yrs; NW CAA, 188 ± 91 ^{14}C yrs; NE Baffin Island, 81 ± 18 ^{14}C yrs; SE Baffin Island, 14 ± 58 ^{14}C yrs; Hudson Strait, -73 ± 64 ^{14}C yrs; Ungava Bay, 0 ± 86 ^{14}C yrs; Foxe Basin, 175 ± 89 ^{14}C yrs; Hudson Bay, -21 ± 72 ^{14}C yrs; James Bay, 209 ± 114 ^{14}C yrs. Species-specific marine mammal ΔR terms are 108 ± 60 ^{14}C yrs for beluga and 9 ± 69 ^{14}C yrs for bowheads.

For the Barents Sea, molluscan ΔR values are: western Svalbard, -61 ± 37 ^{14}C yrs; Franz Josef Land, -277 ± 57 ^{14}C yrs; Novaya Zemlya, -156 ± 73 ^{14}C yrs; N Norway, -86 ± 39 ^{14}C yrs. Cetacean ΔR are: toothed whales, -161 ± 41 ^{14}C yrs; baleen whales, -158 ± 43 ^{14}C yrs; combined baleen-toothed whales, -160 ± 41^{14}C yrs.

Our revised ΔR values are applicable for as long as those broad oceanographic conditions (circulation, ventilation) have persisted, i.e., through much of the Holocene. Whilst molluscan values may be applicable to other marine carbonate materials (e.g., foraminifera), cetacean ΔR terms are valid only for the species they were calculated for and should not be applied to other marine mammals such as polar bears, seals, and walrus.

Building a new amino acid geochronology based on enamel intra-crystalline protein degradation dating of Sicilian dwarf elephants

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The elephants of Sicily are one of the most striking examples of insular dwarfing, a process that is likely to have occurred several times during the Middle-late Pleistocene. Proboscideans are excellent swimmers and appear to have colonised Sicily from the mainland during the Pleistocene, becoming isolated on the island when sea levels changed. Accurately dating the timings of colonisation presents a significant challenge, as several of the deposits are found in cave sites with complex stratigraphy. Numerous techniques have been employed to date the Mediterranean dwarf elephants (e.g. radiocarbon, electron spin resonance, U-series), but none of them can be universally employed. Additionally, application of these techniques has been shown to have a low reliability/precision in many instances, making correlation between sites difficult.

Pioneering work in the 1980s and early 1990s used tooth enamel to date several Sicilian cave sites using the epimerisation of the amino acid isoleucine and kinetic modelling to obtain absolute age estimates. More recently our understanding of the limitations and approach to dating tooth enamel has progressed significantly and we are now able to revisit the direct dating of dwarf elephants using amino acids.

We present here a new relative geochronology for Sicilian dwarf elephants based on intra-crystalline protein degradation of tooth enamel amino acids. By targeting a closed system fraction found within tooth enamel, we negate issues of leaching and contamination, and do not rely on kinetic modelling. By enabling direct dating on the key elephantid material, this provides a valuable approach for hypothesis testing of different evolutionary models.

A Late Holocene isochron for SE Europe based on human-induced Pb contamination

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The integration of the unique archeological/historical record of the Eastern Mediterranean region with Holocene paleoclimate datasets suggests potential causal links between abrupt climate change and sociocultural transitions. To date, however, the study of human-climate interactions during the Holocene in that region remains poorly constrained, with one reason being difficulties in the precise correlation of individual records stemming from dating uncertainties. To circumvent inconsistencies related to regionally variable radiocarbon reservoir ages and/or even to the lack of datable material, direct alignment of regional records can be achieved through the use of event markers. We here introduce a new isochron for the Aegean Sea region based on atmospheric Pb contamination of sediments associated with metallurgy and mining activities in the Late Holocene. Specifically, we examine the geochemical composition of robustly dated cores from across the Aegean Sea region using a combined approach of X-ray fluorescence (XRF) core scanning and inductively-coupled plasma (ICP-MS) elemental concentration analysis. Our results document a synchronous 2–3-fold increase in Pb content from natural background levels at ca. 2.3 kyrs BP, and considerable variability from this time onwards that is uniform across all investigated sites. These results suggest that anthropogenic Pb contamination has left a distinct imprint on regional sedimentary archives over the past three millennia. We suggest that the timing of changes in Pb content can serve as a regional isochron in the Aegean Sea region allowing for the direct correlation of marine and terrestrial records with archaeological soil profiles, thereby circumventing the inherent uncertainties of direct dating techniques.

Sedimentary facies and stratigraphy of late Pliocene-Quaternary shallow-water contourite deposits on the Hupo Basin, East Sea of Korea

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The shallow-water contourite deposits of the Hupo Basin shelf are analyzed using sedimentary structures, grain size textures, sediment color, and Optically Stimulated Luminescence (OSL) and Accelerator Mass Spectrometry (AMS) ages of a long sediment core (19ESDP-101, 120 m). The shallow water contourite deposits can be divided into seven sedimentary facies grouped into four Facies Associations (FA): 1) contourite drift, 2) contourite drift/channel transition, 3) contourite channel/drift transition, and 4) contourite channel. FA1 is interpreted to result from the interaction between hemipelagic, low-density gravity flow and settling induced sedimentation. Both FA 2 and FA3, due to their relative increase grain-size and the presence of subtle indicators of bedload transport, are indicative of higher bottom current compared to FA1. FA 4 shows massive to slightly bedded sand, representing a contourite channel environment related to high energetic conditions. Fluctuations in the bottom current activity, related to the intensification and deceleration of the North Korean Cold Current (NKCC) have primarily caused fluctuations between contouritic and hemipelagic dominated periods. The vertical sedimentary facies stacking patterns observed in the Hupo Basin site suggest that, over time, the depositional processes changed at the site where the sections were located. The facies associations suggest the lateral migration of the contourite depositional system and continuous flow of the NKCC. This study serves as a reference for shallow water contourite recognition both in modern environments and the ancient record. Moreover, by establishing the depositional processes of sediment behavior a schematic model is provided that improves interpretation of the shallow-water contourite deposits.

Holocene Maximum Flooding Surface on the Danube Valley - preliminary results –

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Following the Black Sea reconnection to the World Ocean (ca. 9500 years ago) the sea level rose rapidly, drowning the lower valleys of the Black Sea tributaries and turning them into large rias, some of which remained submerged until today (e.g. Dnister, Dniepr, Don). The Lower Danube Valley (LDV) was not excepted, and recent studies indicate a likely extension of the marine waters in the early Holocene beyond its current delta apex. In the present study, we track the Maximum Flooding Surface (MFS) in the LDV, identifying the most landward position of the transgressive systems tract in terms of stratigraphy and brackish microfauna. For this purpose, preliminary results performed on five cores (12 - 16 m long) from LDV are presented. These cores have been analyzed for multiple proxies, including 14C datings, grain-size, loess on ignition, magnetic susceptibility, and microfauna (ostracods and foraminifera). Four main depositional facies have been identified (A-D in ascending order): Facies A is composed of massive fluvial sand that became laminated and finer to the top; Facies B is laminated, very fine sand with mud drapes, and contains brackish microfauna; Facies C and D are represented by floodplain deposits composed of multiple layers of sand and mud (C) and by mud and peat (D). Facies B has a thickness between 1 and 8,5 meters, dated between ~8000 and 7200 cal yrs BP, when the stratigraphy turnaround from retrogradational to progradational one. It has a big sedimentation rate (>3mm/y) in a period with a rapid sea level rise, so in this facies interval lies the MFS. The presence of brackish microfauna in SRT core, ~140 km inland from the present river mouth, implies that the brackish water of the Black Sea reaches the confluence between Siret and Danube at about 1500 years after the reconnection with the Mediterranean Sea.

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Pleistocene paleoenvironmental reconstruction from subsoil dataset: from neritic to fluvioglacial domain in the upper central Po Plain (N-Italy)

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The Po Plain (N-Italy) is a foreland sedimentary basin bounded by two mountain ranges (the Alps to the North and the Apennines to the South), controlling its sedimentary facies and body geometries. However, the Quaternary succession of the Po Valley is mainly sealed in the subsurface: outcrops are scanty, and data from the few deep wells are not easily accessible. Therefore, data derived from perforation cuttings of water wells are a useful tool to investigate the buried stratigraphy and to better constrain subsurface geological reconstructions and correlations. Detailed sampling of sediments from cores and a high density of sampling sites over the region add important information about lithostratigraphy, micropaleontology and sedimentary source area, allowing the detailed reconstruction of the Pleistocene paleoenvironmental evolution of the Po Plain. We present data from a selection of boreholes from a repertory of ca. 35 wells drilled in the upper central part of the Po Plain, including the description of cores sedimentology, petrography, and fossil content. The studied boreholes implement the database of the area and add new significant evidence to interpret and correlate the subsurface stratigraphy of the Po Plain to the regional dynamic from the Lower Pleistocene to the end of the Last Glacial Maximum (LGM). At the bottom of most of the selected boreholes, transitional-marine and marine deposits, dated thanks to their foraminiferal assemblages to the Lower Pleistocene (Gelasian-Calabrian), are preserved. Micropaleontological data allow the correlation of these layers to the neritic domains of the Pleistocene regressive sequence of N-Adriatic Sea and Po Plain. The overlying Middle-Upper Pleistocene continental succession documents the transition from a distal alluvial plain, characterized by meandering rivers evolving in deltas and lagoons, to a proximal alluvial plain, formed by the migration of braided river systems. Finally, in the LGM an outwash plain formed in front of the glacial systems located at the southern foothills of the Central Alps.

The impact of precipitation and temperature shifts on the Levant basin during late Pleistocene: assessment from biological and geochemical indicators from Lake Hula, Israel

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The Levant is known to be a sensitive region responsive to any small-scale hydro-climate variability in the geological past. Recently, recurring draughts, temperature extremes and increased in anthropogenic activity have heavily affected the region which in turn might have played a key role in local geopolitical instabilities. Terrestrial archives from this region can thus be valuable sentinels to understand the unique patterns of natural climate variability and its forcing factors, as well as their ecological and environmental impacts. A multi-proxy approach is applied on a >160 m long sedimentary record from Lake Hula to identify the possible impact of precipitation and temperature changes on the hydrological system during the late Pleistocene. The analysis include sedimentology (grain size), geochemistry (elemental content, mineralogy, total organic matter content), and biological proxies (ostracods), in order to reconstruct the processes occurring both within the limnic environment and the terrestrial surroundings. Initial investigation of the lithology and elemental ratio concentrations shows alternating intervals that appear to be associated with low runoff from the lake catchment (identified as a decrease in allogenic minerals and increase in authigenic components), intercalating with intervals characterized by an opposite trend. This initial interpretation implies intercalation between dry and wet climate conditions. Furthermore, variations in the sediment lithology and geochemical proxies suggest fluctuations related to the dominating precipitation regime (winter rains from the Mediterranean), thus proposing that a millennial-scale orbital forcing variability could potentially be disentangled out from the record, as it is well constrained by the chronology. In parallel, Ostracods taxa identification and associated analytical measurements are highly important for assessing the salinity of the lake waters, depths, temperature, Hydraulic condition, bottom grain sizes or sedimentation rate. Moreover, by reconstructing the reaction of the lake system to hydro-climate variability through time, we can better disentangle the current impact of anthropogenic stress and assess future trends. Overall, this study provides a comprehensive picture of the different mechanisms driving abrupt climate changes in the region and explores their potential relevance to future climatic studies.

Stratigraphic and sedimentological features of lower Pleistocene deposits in the geological Sheet n° 628 "Sciacca" (south-western Sicily, Italy)

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As part of the Italian National Cartography Project (CARG) at 1:50.000 scale, we carried out geological field surveys and in-depth sedimentological, biostratigraphic and structural investigation on the lower Pleistocene sedimentary successions outcropping in the Sheet 628 "Sciacca".

In the studied area, located in south-western Sicily, lower Pleistocene deposits belong to different formations, respectively:

- **M.te Narbone Fm.** (NAB): light grey marls and slightly silty clays alternating with grey to brown clayey-marly levels (sapropel layers), with abundant planktonic and benthic foraminifera, calcareous nannofossils and mollusks specimens; it deposited during the middle Piacenzian – earliest Calabrian (Santernian) age in upper slope environment.
- **Agrigento Fm.** (AGG): yellow, slightly quartz calcarenites and sands alternating with sparse, thin levels of bio-calcirudites and conglomerates, with abundant bivalve shells, gastropods, echinoderms, bryozoans, corals, vermetids, rhodoliths; some calcarenite horizons display cross lamination and prograding geometry; levels with finer grain size (pelites and arenitic marl) sediments are also present. At places, arenitic and pelitic levels are organized in shallowing-upwards packages cyclically arranged. The AGG deposited during the lower and middle part of the Calabrian stage (Santernian - Emilian) in a coastal-inner shelf environment.

In the area of Sheet 628 "Sciacca", the stratigraphic transition between these two formations is continuous, gradual and characterized by a progressive enrichment in the sandy fraction. It crops out as weakly cemented arenitic levels in the upper portion of the NAB, followed upward by increasingly thick and cemented calcarenitic horizons up to about ten meters thick that are typical of the AGG.

Lithofacies of such transition highlights a regressive sedimentary evolution from a slope environment with hemipelagic sedimentation to a neritic-littoral environment with hybrid mainly bioclastic carbonate sedimentation and variable inputs of detritic quartz.

Given these general characteristics, some differences exist in the sedimentological features and vertical organization of the lower Pleistocene successions (NAB+AGG) between the western and the eastern sectors of the Sheet 628 "Sciacca". These variations are probably due to the different structural positions occupied by the sedimentation basins where the two successions accumulated: the wedge of the Gela Thrust Wedge to the east and the Sicilian orogenetic wedge to the west.

Tectonic and morphological factors controlling the contrasting stratigraphic setting of late orogenic intermountain basins: a comparison between the Norcia and Amatrice basins, Central Apennines of Italy

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Norcia and Amatrice basins are two late orogenic intermountain basins, located in the Central Apennines of Italy, bordered by active and seismogenic normal faults, active since Late Pliocene.

The 2016-2017 seismic sequence in Central Italy produced a dramatic devastation in both these valleys, despite of the diversity of the contexts: although the Norcia and Amatrice basins are spatially very close and of similar size, they are quite different from a morphological point of view, as well as for their geological evolution and subsoil architecture, i.e. thickness of the Quaternary infill and nature of the bedrock.

The present work is devoted to model the contrasting subsoil setting of the Norcia and Amatrice basins, analysing the factors which controlled their different tectono-sedimentary evolution.

To this purpose, available measurements from existing databases were examined and elaborated, aiming to reconstruct the internal geometry of the basin infilling and first of all the bedrock topography.

The spatially continuous sedimentary succession infilling Norcia basin reaches an extimated maximum thickness - still debated in bibliography - between 350 and 600 m in the depocenter, located in the south-western portion of the Norcia settlement. The continental succession, covering a Mesozoic-Paleogene carbonatic bedrock, includes about 100 m of lacustrine deposits, passing upward to fluvial body and alluvial fan. Although the eastern flank of the basin is bordered by the Norcia normal fault, with antithetic faults on the opposite flank, the very thin sedimentary infill of the southern half of this basin suggests that the tectonic activity is not the only factor controlling the sedimentary infill distribution.

In the Amatrice basin, the Quaternary succession, superposed to a Miocene turbiditic substratum, is distributed in several, localized minor remnants. The terraced succession, whose maximum thickness reaches 60 m, doesn't include lacustrine deposits but only fluvial and alluvial fan on a hiatus and erosional vacuity. Here, the local subsidence due to normal faulting and the concurrent regional uplift did not offer a suitable accommodation space to develop a thick basin, and the subsequent fluvial incision contributed to reduce the thickness of the post-orogenic sedimentary succession.

The Paglia - Tevere Graben, Italy: Plio-Pleistocene sedimentation and structural architecture

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Extensional basins in retro-arc and hinterland areas allow sediment accommodation and preservation of thick coverage in well organised depositional sequences. The Peri-Tyrrhenian area of northern-central Apennines (Italy) is characterised by a widespread occurrence of syn-tectonic basins framed within a horst-and-graben structural setting produced in response to the SW-NE trending continental extension since the Miocene.
Among these syn-tectonic basins, the Paglia-Tevere Graben represents a 60 km long, NNW-SSE-striking morpho-structural depression hosting marine-to-continental Plio-Pleistocene sediments up to 1 km-thick lying above substrate made of turbiditic sequences. The Plio-Pleistocene sedimentary succession is organised in two main syn-rift and high rank depositional sequences, from the open marine to coastal-transitional environments: the first one is Zanclean-early Gelasian in age, while the second spans from the late Gelasian to the early Calabrian. The continental succession ends with post-rift and syn-uplift fluvial terraces, travertines and volcanic deposits of the Vulsini Volcanic District, since the late Calabrian (1.3 Ma).
Detailed surveys and geological mapping, combined with an intense bibliographic review of biostratigraphic, tephrostratigraphic and strontium isotopes data, were performed to improve the knowledge of the geological evolution of the graben in its northern part. Stratigraphic and sedimentological analyses have been devoted to detail the stratigraphic organisation of the Plio-Pleistocene sequences. We identified: i) minor transgressive-regressive cycles associated with recurrent stages of west-directed progradation and retrogradation of coarse-grained fan-deltas sourced from the western mountainsides of the Apennines; ii) transgressive marker beds of bioclastic calcarenite levels with *Amphistegina* (zone MPL5b), as indicators of climate warm phase.
The structural analyses revealed the occurrence of multiple fault sets, variably dissecting both the Plio-Pleistocene sequences and the Miocene turbiditic substrate. A polygonal setting (in map view) of normal faults occurs in the eastern part of the graben, represented by decametre-to-hectometre-long fault segments striking NW-SE, N-S, and NE-SW, and accommodating a cumulative stratigraphic offset of tens of metres. Strike-slip faults, mostly striking NNE-SSW, locally cut the normal ones, contributing to the disarticulation of the morphostructural basin. Our preliminary data can be used to constrain the geometry, the opening rate and the sedimentary evolution of the Paglia-Tevere Graben during the Quaternary.

Reconstruction of a 3D geological model of the quaternary deposits filling the Cassino intramontane basin (central Italy)

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The aim of this work is to show how classical geological investigations and geophysical measurements can be combined with implicit 3D modelling to reconstruct detailed geological models of quaternary intramontane basins and to describe the relationship between the different lithological bodies composing the post-chain filling deposits.

To this aim, has been chosen the urban area of Cassino in southern Lazio ((central Italy). The area is located at the end of the Latina Valley, and it is bordered by the carbonate structures of Mt. Cairo to the NW, Venafro Mts. to the NE and SE, and several main tectonic elements mainly in Apennine development.

For reconstructing the lithostratigraphic structure of subsoil, about 200 stratigraphic surveys and about 100 seismic noise measurements were analyzed and homogenized. These have been correlated with the deposits and depositional environments described in the literature. Seven main stratigraphic units were recognized. The results show that the carbonate bedrock is very articulated because of tectonics. On its top, lies a clay and sandstone unit attributable to the Frosinone Flysch (Upper Miocene), followed by a complex of alloantigen series attributable to a generic Messinian sea-lake environment (Lower Pliocene). These sediments are covered by the lacustrine sequence of the *Lirino* Lake, formed by an alternation of clayey silt and sand with gravel, with thicknesses ranging from a few meters near the carbonate reliefs up to about 150 m in the NW of the Cassino urban area. It should be noted that this sequence, close to the relief of Mt. Cassino, is characterized by the presence of layers of gravel and sand attributable to the *Paleo-Rapido* riverbed, today diverted by anthropic activity, which probably constituted an ancient tributary of the *Lirino* Lake, which occupied the Cassino plain in geological times. Traces of the course of the *Paleo-Rapido* riverbed can also be observed in the buried morphology of the carbonate Bedrock.

The characterization of the subsoil has led to the definition of a conceptual geological model that highlights the persistence of the condition of the river-lake environment at least until the end of the Late Pleistocene.

Pliocene-Pleistocene interregional unconformities in the Apulian Swell and Bradano Foredeep Basin as tracers of oblique plate collision and orogenic translation of the surrounding collisional belts (Northern Ionian Sea - Central Mediterranean)

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The Apulian Swell and the adjacent Bradano Foredeep Basin, along the Africa/Adria/Eurasia plate boundary, represent a natural recorder of Pliocene-Pleistocene tectonic processes due to their location between Southern Apennines (SA), Calabrian Arc (CA) and Dinarides/Hellenides. Integrated analysis of seismic reflection profiles, exploration well logs, and seafloor bathymetry, allowed us to unravel the basin architecture and the interplay between tectonics and sedimentation, providing stratigraphic and structural evidences on deep processes and shallow morpho-structural development. We find that the Pliocene-Pleistocene tectonic evolution is marked here by two major tectonic events, whose effects are recorded in four sedimentary sequences bounded by inter-regional unconformities. They were related to 1) flexure/bending of the subducting Adria plate, under the load of the advancing Calabrian Arc and Hellenic wedge; 2) buckling in response to compression of the surrounding orogens (southern Apennines, Hellenides); 3) roll-back and eastward retreat of the Adria plate. During Pliocene times, an obliquely convergent margin led to collision between SA and CA, associated to turbidite deposits in the continental shelf and the deep basins. Around the Pliocene-Pleistocene boundary (2.58 Ma), a sudden and widespread rearrangement took place. The SA front, along with portions of the earlier obliquely collisional margin, started to move toward the NE, through progressively deeper detachments involving the lower Adria plate. During this phase, a fast translation of the SA orogenic wedge was followed by uplift and shortening, associated with folding reaching up to the seafloor. This second phase is marked by deep marine deposits in the central part of the basin, and clinoforms in shallower western and northern sectors. At the same time, the Apulian Swell, affected by inherited and rift-related Permo-Triassic normal faults, shows transpressive and positive tectonic inversions followed by extension, related to the coeval advancement and shortening of the Hellenic fold/thrust belt. The complex deformation pattern observed represents the response to the interaction of (small-) plates, which is still active and important to be considered in neotectonics and paleoseismological reconstructions.

Geological investigation of mud volcanoes in the periadriatic area of the central Marche region: fluid circulation models

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Mud volcanoes are the surface expression of geological subsurface processes system characterized by transport of large volumes of sediments and fluids (water and gases). The subsurface processes may also create piercement structures such as diapirs and domes, not necessarily generating a mud volcano. The main driving mechanisms of the mud volcanism correspond to a combination of gravitative instability of sediments, and pressure of the hydrostatic system (i.e., overpressure of gas) allowing the migration through fractures or faults zones.

This work is framed in a macro project focused on investigating the geological and mineralogical characteristics of a series of mud volcanoes distributed along the eastern thrust fronts of the Italian peninsula, more precisely in the Marche region. These structures are distributed on a monocline (NE-dipping) composed by Miocene and Plio-Pleistocene deposits, covering several thrust-related folds and thrust faults in the peri-Adriatic area. The geometry and the mud source of these mud volcanoes are poorly studied.

Here, we present preliminary results of an integrated methodology (geophysical, mineralogical and micro-paleontological) applied on a key mud volcano located at Monteleone di Fermo to characterize its structure at local scale and the mud source. To reconstruct the 3D subsurface model, a 3D Electrical Resistivity Tomography (ERT) was performed using a FullWaver system (Iris) allowing to determine the near-surface (depth <100m) geometry of a mud volcano. To investigate the possible sources of the solid fraction of the erupted muds and consequentially to reconstruct a probable fluid migration pathway, we have integrated mineralogical (Powder X-Ray Diffraction and Scanning electron microscope) and micro-paleontological investigation.

We expect to provide new insight about source(s) and composition of the erupted material, proposing a new migration model involving high angle faults. Our study may serve as example methodology for the characterization of similar mud volcanoes in the area. Also, the circulation models and the mud apparatus' reconstructed geometry, can be used as an analogue element to characterize off-shore mud volcanoes and cold seeps in general.

Paleomagnetism and rock magnetism from sedimentary core collected in the NW Barents Sea in the framework of PRA2021-IRIDYA project

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We present a paleomagnetic and rock magnetic dataset from sedimentary cores collected in the NW Barents Sea. This investigation is conducted within the framework of project PRA2021- IRIDYA (Integrated reconstruction of ice sheet dynamics during Late Quaternary Arctic climatic transitions). All the analyzed cores show consistently good paleomagnetic properties, which allow for the reconstruction of well-defined characteristic remanent magnetization (ChRM) throughout the sedimentary successions. Rock magnetic and paleomagnetic parameters were used for high-resolution continental margin cross correlation with other existing cores. Moreover, the paleosecular variation (PSV) and relative paleointensity (RPI) trends of geomagnetic field have been defined, providing chronological constraints for the ages and rates of past depositional events. The results from this study allow us to tie-in cores collected far from each other and distributed along a 330 km-long transect crossing the north-western margin of the Barents Sea and western margin of Spitsbergen, providing a set of information that can be used as a benchmark for the reconstruction of the paleoclimatic evolution of this region.

Sedimentary architecture of submarine mid slope deposits with relics of gas hydrate fractures revealed by X-ray CT scanning: new insights from the Tuaheni Landslide Complex, North-East of New Zealand

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The Hikurangi subduction margin in northern New Zealand is a seismically active zone that triggered a great number of submarine mass-transport deposits. It is also well-known for free gas and gas hydrates occurrences in near-seafloor sediments., including close to the Tuaheni Landslide Complex (TLC). Among the multiple submarine deposits associated to the TLC, the T2 deposit was interpreted as a creeping submarine landslide considering its uncommon morphology and chaotic signature on seismic data. In 2017, IODP 372 Expedition collected c.200 m-deep drilled cores through the entire T2 deposit. High-resolution line and X-CT scans on these cores allow to precise the composition and internal architecture of the T2 deposit in terms of lithology, deformation and sedimentary structures. X-CT data reveal the occurrence of low-density, near-vertical structures invisible to the naked-eye that are here, interpreted as relics of gas hydrate filled-fractures. Thus, we propose to re-assess the nature of the T2 Deposit as a marine composite sedimentary complex with a basal and multiple internal weak-layers, formed by sea level variations since the Late Pleistocene. A surficial mud-flow deposit (< 11 ka) potentially emplaced after a seismically-induced event, buried hydrate-bearing sediments below the BSR, driving gas hydrate dissociation and weak layers formation. These results bring new evidence for gas hydrates implication into slope instability processes and marine geohazards.

Poster - sessions 4, 47, 85, 103, 118, 148, 162, 173, 176, 177

Reconstructing pattern of multiple sub-stages of sediment deformation during single seismicity-induced liquefaction event (Dyburiai, NW Lithuania)

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The study presents the results of micro-scale analysis that supplements the mesoscale investigation of the unconsolidated lacustrine sandy and silty sediments, deposited during MIS 5d, at Dyburiai study site in north-western Lithuania. Detailed macroscale analysis of the 4.5-m thick sediment succession revealed ten internally deformed layers with exceptionally well-developed liquefaction-induced soft-sediment deformation structures (SSDS), interbedded with undeformed sediments. Erosional features at the tops of the layers containing SSDS clearly indicate that the multiple deformation events were separated by periods of erosion, followed by the subsequent deposition of new sediments. Consequently, it is concluded that the likely trigger mechanism for the sediment deformation was recurrent phases (at least seven) of seismic activity. Seismic activity was most likely caused by reactivation of a fault within the sub-Quaternary substratum in response to ice unloading during Saalian deglaciation.

Four thin sections, prepared from undisturbed oriented samples collected from the different sediment layers containing SSDS, were analysed to constrain the processes accompanying deformation. The recognized microstructures include, injection structures (sand-filled veinlets), disharmonic synforms (load casts), pseudonodules, recumbent folds, detachments, subhorizontal shears and small-scale faults. The thin sections reveal that the relative intensity of the deformation is highly heterogeneous. In some areas of the thin sections the primary sedimentary structures are still visible, however elsewhere within the same thin section the sediments are highly deformed and disrupted. In some cases, the highly deformed sediments occur between laminae of low-permeable silt or clay. Cross-cutting relationships between the deformation structures indicate that soft-sediment deformation accompanying each seismically induced liquefaction event consisted of numerous successive stages: (1) initial recumbent folding and thrusting, (2) liquefaction and sediment injection (hydrofracturing) often accompanied by faulting, and (3) compressional folding. The results indicate that individual liquefaction processes affecting any layer with SSDS consisted of multiple deformation stages generating complex deformation microstructures.

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Trenching and geophysical investigation of recent faulting in Late Pleistocene to Holocene fluvial deposits within the Júcar Valley (Valencia, eastern Spain)

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This work presents the results of a trenching and geophysical investigation conducted in a late Pleistocene terrace affected by normal faulting and underlain by salt-bearing bedrock of a diapir. The study area is located in the 34-km-long, N-S trending Ayora-Cofrentes graben at the junction zone between the Betic Cordillera and the Iberian Chain, eastern Spain. This 5-6-km-wide graben has a continental Mio-Pliocene fill pierced by a salt wall of Triassic evaporites along its axis, that splits the basin into two half-grabens. The normal faults bounding the Ayora-Cofrentes graben offset up to several hundred meters Jurassic to Miocene formations but are onlapped by Pliocene lacustrine limestones that record the final stages of the endorheic basin fill. Quaternary fluvial incision governed by the Júcar River base-level has generated deeply entrenched longitudinal and transverse valleys across the uplifting diapir, locally forming nice examples of drainage antecedence. Here, the river has developed a sequence of 14 terraces from +130-135 m. This work focuses on N-S-oriented normal faults spatially associated with salt-bearing units of the salt wall that offset the +25-30 m terrace (T9) of the Júcar River, dated by U/Th and OSL at ca. 90-132 ka (MIS 5). ERT sections acquired across the fault zone in the terrace underlain by evaporitic bedrock revealed a lineal collapse structure with a throw of around 30 m. A 108 m long and 4.5 m deep trench was excavated across the main west-facing fault scarp and the associated trough, exposing a 64 m wide half-graben structure. A long-term slip rate of 0.015-0.03 mm/yr has been estimated considering the net throw (3.1-3.9 m) and the maximum age of the terrace. The stratigraphic and structural relationships reveal an episodic displacement regime for the fault system, with a minimum of three faulting events at: 137-127 ka (X), 99-90 ka (Y) and ca. 2.8 ka (Z). The spatial association of the deformation with the Triassic halite-bearing bedrock (Keuper), and the lack of clear offset across the collapse structure imaged in the ERT section suggest a gravitational origin, despite some tectonic influence by basement faults cannot be ruled out. FUNDED BY MINCIN-FEDER 2021-123510OB-I00

New paleoseismological studies in the Rieti intermountain basin (Central Italy)

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In Central Italy, the damage induced by the 2016-2017 seismic sequence to the building and infrastructural heritage and the need to consider the surface fault rupture hazard in the reconstruction process incentivized Seismic Microzonation studies focused on capable faults. The presence of capable faults, that produced dislocation of the ground surface at least once within the past 40.000 years (cf. Italian Civil Protection guidelines), is, in fact, one of the exclusion criteria for post-earthquake reconstruction.

In 2020-2022, the Italian Government Extraordinary Commissioner for post-earthquake reconstruction funded a program of studies on capable faults affecting urbanized zones in the epicentre area. Some of the inhabited centers being studied are located along the NE, E and SE borders of the Rieti intermountain basin.

The formation and evolution of the box-shaped Rieti basin is closely related to the extensional regime that affected the western flank of the eastward migrating Apennine chain during the Quaternary, in combination with regional uplifting. During the Early Pleistocene, the evolution of the basin was controlled by a normal fault located along the eastern edge, with NNW-SSE orientation. This structure acted as a master-fault, determining a progressive deepening of the half-graben, thus favoring the deposition of thick sequences of fluvial deposits, first of alluvial fan (Fosso Canalicchio Synthem) and then alluvial plain (Monteleone Sabino Synthem) facies. The E-W oriented structures along the northern and southern margins of the basin acted as transfer structures, linked to the eastern border fault. During the Middle Pleistocene, along the margins of the basin, the Early Pleistocene deposits were displaced by a few hundred meters, developing a further deepening of the Rieti basin and the northward diversion of the hydrographic network of the Velino River.

The 17 new paleoseismological trenches, with 52 radiometric dates and extensive geophysical prospecting, carried out in 2021 and 2022 by ISPRA and Insubria University with INGV, discovered Late Pleistocene and Holocene activity along the investigated faults. The collected data will be analyzed at the basin scale to reconstruct recent tectonic activity, define the current seismic hazard and recognize the possible presence of seismic cycles in the Rieti Basin.

Towards deciphering past seismic activities of the North Tehran fault through the dating of colluvium and fault gouge

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The North Tehran fault (NTF) is the main tectonic structure of the megacity of Tehran. It extends over 68 km along its northern fringe and has received considerable attention in the context of geohazard analysis. However, our knowledge about past major activities is limited to only a few studies in which the activity of the NTF has been probed by identifying offsets of geomorphic features or distinct stratigraphy. Notwithstanding, the historical records suggest the occurrence of major devastating earthquakes on this active structure.
In this study, we aim to apply luminescence-dating methods that have proven applicable in earlier studies in the region to constrain the timing of the last activities throughout the Late Quaternary. Our research is twofold and consists of indirect and direct dating of past earthquakes. In our contribution, we will present the first dating results of our first fieldwork season. Samples have been taken from several Quaternary colluvial and alluvial units in various spots along the NTF linked to seismic activity-caused ruptures. More importantly, our work includes the first results of luminescence dating of fault gouges along the NTF. With this, we respond to the research question as to whether the fault gouge dating, in combination with the luminescence technique, is a promising approach to reveal the timing of past earthquakes along the NTF.

Paleoseismic studies of the Rhine Graben Faults (Germany)

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The Rhine Grabens in Central Europe are one of the most seismically active intra-plate regions and host damaging earthquakes in historical times (e.g., the 1356 Basel earthquake, Düren 1756, Verviers 1692), all below M 7. During the last decades, several research efforts have been undertaken to characterize the seismic hazard associated with the Rhine Grabens and have focused mainly on the western margins of the grabens unraveling Upper Pleistocene-Early Holocene surface rupturing faults. However, paleoseismic studies resulted in incomplete estimations of the faulting history and the seismic potential of the faults, because the models applied incorporate “period and characteristic” fault theories in earthquake geology. Our research aims to characterize the seismogenic faults Rhine Grabens by studying their neotectonic imprint in the landscape and establishing a chronology of seismic events along each fault or fault segment. We performed geomorphological mapping of faults, Quaternary deposits, trenching of paleoseismic features and calculated several morphometric parameters to depict fault segmentation along the faults and include long-term deformation. We provide data that prove the kinematics of the faults and allow us to define areas with varying tectonic activity. We trenched several sites for paleoseismological studies including extensive geophysical surveys in the Upper and Lower Rhine Grabens: 1) six trenches along and across the secondary topographical fault scarp of the eastern Rhine Graben Boundary Fault north of Ettlingen-Oberweier (Karlsruhe); 2) three trenches across the Rhine River Fault scarp, which cuts the distal parts of the Neumagen alluvial fan near the village of Tunsel (Freiburg), and; 3) and two trenches across the Feldbiss Fault near Aachen. In all study sites, we found surface rupturing earthquakes providing the first evidence of Late Pleistocene and Holocene tectonic activity with M >6 and, hence, we contribute significantly to the completeness of the earthquake history.

Inheritance of Detrital Charcoal and lacustrine shells: Implications for Age Estimates on Paleoearthquakes

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We have compiled over 900 stratigraphically constrained radiocarbon dates from seven stratigraphic sequences to determine the extent to which detrital charcoal and lacustrine shells are either reworked or carry inherited age. We combine 296 dates (out of 423) from Lake Cahuilla (Rockwell et al. 2022) with 95 dates from a new study at Salt Creek, also from Lake Cahuilla, and show that nearly half of all dates are older than underlying strata, indicating significant age inheritance. Similarly, inheritance ranges between 30% for the Old Town site along the Rose Canyon fault to 41% at the Mystic Lake site along the San Jacinto fault, to 44% at the Beteiha site along the DST. In contrast, 111 dates from Hog Lake (Rockwell et al., 2015) show that only about 15% of dates exhibit ages older than underlying strata, but most dates were on seeds contained in thin organic mat layers, all of which were in stratigraphic order. Hence, it is clear that chronologies constructed from single year growth samples substantially improve the accuracy of the ages of individual strata. Dates on lacustrine shells maye ven be worse in terms of reworking. We dated 32 samples of gastropods from a single lake sequence along the San Andreas fault and found that 90% exhibit age inheritance. Similarly, we dated 23 gastropod shells from two cores on the Colorado River delta that exhibited similar results. The percentage of reworked or older charcoal and Shell indicates that paleoseismic studies should consider dating twice as many samples as are expected to define an age sequence. Further, whenever possible, single-year growth samples, such as seeds and pine cones, should be dated to help constrain and anchor a chronologic model. These statistics have broad implications not only for paleoseismic studies, but for fire frequency and slip rate studies. Reliance on a single date to quantify processes or events appears to be quite risky.

Deformation History of the Pohang Basin in the Heunghae area, Pohang and Consideration on Characteristics of Coseismic Ground Deformations of the Pohang Earthquake, South Korea

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On November 15, 2017, a Mw 5.4 Pohang Earthquake occurred at about 4 km hypocenter in the Heunghae area, and caused great damages to Pohang city, South Korea. In the Heunghae area, which is the central part of Pohang Basin(PB), Cretaceous Gyeongsang Supergroup and Late Cretaceous to Early Paleogene Bulguksa igneous rocks as basement rocks, and Neogene Yeonil Group as fillings of PB, are distributed. In this paper, structural and geological researches on the crustal deformations(folds, faults, joints) in PB and the coseismic ground deformations(sand volcanoes, surface cracks, pup-up structures) of Pohang Earthquake were carried out, and the deformation history of PB and the characteristics of coseismic ground deformations were considered. The crustal deformations were formed through at least five stages before the Quaternary faulting: forming stages of the normal-slip(Gokgang fault) and sinistral strike-slip faults which strike (N)NE and dip at high angles, and the high-angle joints of E-W trend regionally recognized in Yeonil Group and the faults (sub)parallel to them, and the conjugate normal-slip faults(Heunghae Fault and Hyeongsan Fault) which strike E-W and dip at middle or low angles and the accompanying E-W folds, and the conjugate strike-slip faults dipped at high angles in which the (N)NW and E-W or NE striking fault sets show the (reverse) sinistral and dextral strike-slips, respectively, and the conjugate reverse-slip faults in which the NNE and NNW striking fault sets dip at middle angles. Sand volcanoes often exhibit linear arrangements (sub)parallel to surface cracks. The pop-up structures and surface cracks of N-S or (N)NE trend and surface cracks of E-W or (W)NW trending among the coseismic ground deformations were formed by the reverse-slip movement of the earthquake source fault and the accompanying buckling folding of its hanging wall due to the maximum horizontal stress of Pohang Earthquake source. These structural activities occurred extensively in the Heunghae area, Pohang, which is at the hanging wall of the earthquake source fault, causing enormous property damage here.

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Recent improvement of the Active Fault Database of Japan

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1. Geological Survey of Japan/AIST

Geological Survey of Japan/AIST has opened the Active Fault Database of Japan since 2005. It includes not only the active fault traces but also fault parameters obtained from field surveys by local governments, university groups as well as our institute. We started to improve this database recently and show detailed active fault maps for each segment, including fault traces and investigation sites. We also add several fault segments, which were included in the government reports. Accuracy of location of fault traces and investigation sites are improved in order to show them on the 1:50,000 scale map. In the detailed fault map, we add symbols to indicate the faulting sense (reverse, strike-slip, normal) and certainty of fault trace. We will open these new data for each fault segment one by one and will complete all segments by 2030FY in the current plan.

Active faulting in the eastern and central Mediterranean basin

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We present an overview of results from the Leverhulme Trust 'NEPTUNE' project in which we combine observations of onshore and offshore active faulting in the eastern and central Mediterranean to build an overall appreciation of structural development, rates of deformation, and earthquake and tsunami hazard. We use compilations of seismic reflection data and EMOD bathymetry to identify basement faults, and to separate these few major features from more superficial deformation within and above the Messinian salt horizons. Since the late Miocene active faulting within the Mediterranean basin, and along its onshore eastern and northern margins, has had profound effects on the regional organisation of drainage networks that, in turn, affected the inputs of freshwater into the marine basin. Tectonic forcing of freshwater and clastic inputs has generated characteristic marker horizons and facies, such as the Messinian post-evaporitic clastic units, which are used to estimate long-term displacements and rates of faults, from the Messinian to present.

The Montereale basin: tectonic and sedimentation in a central Apennine intermontane depression.

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The relationships between quaternary tectonic and sedimentation were investigated in the intermontane Montereale Basin (MB), in the axial sector of the central Apennine.
The quaternary faults interacting with the sedimentation of the MB basin are represented by the Capitignano Fault (CPF), bordering the basin to the NE, and the San Giovanni Fault (SGF) in the center of the SW sector of the basin. These tectonic elements guided the development of two distinct depocenters with differences in their evolution and thicknesses (the Capitignano and the Piedicolle sub-basins).
Despite the scarce exposure of the Quaternary deposits, the reconstruction of the stratigraphic record was possible by integrating field mapping with geophysical studies, core drillings, paleomagnetic analyses, and ^{14}C and ^{39}Ar/^{40}Ar dating. Obtained data suggest that in the first phase of the sedimentary evolution of the basin, the fault-related subsidence exceeded the sedimentation rate, allowing the persistence of lacustrine sedimentation. Subsequently, between the Early Pleistocene and the Middle Pleistocene, a slowdown in the activity of both the CPF and SGF allowed the threshold between the two depocenters to be overcome and consequently the establishment of a drainage pattern similar to the current one. Thus, the MB has followed the same evolutionary pattern recognized for other intermontane basins in the Central Apennines and it has been rather early integrated into the regional hydrographic system (Early-Middle Pleistocene transition?).
To verify the activity and quantify the slip rates of CPF and SPF during the late Pleistocene-Holocene a total of three paleoseismological trenches were dug. These allowed to estimate a slip-rate of about 0.3 to 0.4 mm/yr during the late Pleistocene-Holocene for the CPF and SGF.
Thus, despite the two faults can still be classified as active and capable, since the late Middle Pleistocene, alternating aggradation and erosive episodes, suggest that the tectonic subsidence was no longer able to compensate for the sedimentation rates and therefore the evolution of the basin was essentially controlled by external factors (e.g. lowering of base level).

Seismotectonics review and 3D rheological modelling of the Durres area (Albania)

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The Durres sector of the Adria-Eurasia collision was recently affected by the 2019 seismic sequence. The seismogenic volume belongs to the active portion of the accretionary wedge representing the external part of the Albanides fold-and-thrust belt. In this sector, the front is kinematically partitioned by the ENE-WSW Shkodra (to the North) and Lushnje (to the South) transfer faults (Caputo and Pavlides, 2013). This region shows a documented seismic activity (Baker et al., 1997; Louvari et al., 2001; Muco et al., 1994) associated to both thrust and back-thrust structures (Muceku et al., 2006; Roure et al., 2004; Skrami et al., 2001; Velaj et al., 2001), though the orientation of the causative source of the 26 November, 2019 Durres mainshock (Mw=6.4) is still debated. In order to better characterize the seismogenic sources recognised in the area (from GreDaSS database; Caputo and Pavlides, 2013), we performed a seismotectonic review and created a 3D rheological model for constraining their (maximum) seismogenic potential. The BDT (Brittle Ductile Transition) represents a good proxy of the seismic/aseismic transition and fundamentally corresponds to a mechanical boundary for coseismic rupture propagation processes (Maggini and Caputo, 2021). Close to this mechanical and behavioural transition, quasi-continuum deformation within the viscous crustal body generally induces elastic deformation within the contiguous elasto-brittle body; therefore, when sufficient energy is accumulated it is commonly released seismically. Following a similar approach by Maggini and Caputo (2020, 2021) for the broader Aegean Region, we compared the seismicity cut-off depth of the investigated sector with the modelled BDT depth, thus confirming that the rheological and seismological transitions are tightly correlated. Our model, based on dedicated MatLab scripts and proper calibrated input parameters, evidence the presence of different superposed brittle and ductile layers (clearly evident in transversal reconstructed 2D sections) within the modelled volume. The maximum seismogenic depth occurs at values ranging between 10 and 25 km. Finally, based on the inferred source parameters and applying appropriate empirical relationships (Wells and Coppersmith, 1994; Leonard, 2014), we estimate the maximum expected magnitude for each source and hence their contribution for the Seismic Hazard Assessment of the area.

Spatial evolution of warming across the Chinese Loess Plateau over the last deglaciation

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The East Asian Summer Monsoon (EASM) is driven by changes in the land-ocean thermal gradient, and is expected to strengthen in response to global warming. Previous studies suggest that peak EASM intensity gradually migrated northwestward over the Chinese Loess Plateau (CLP) over the last deglaciation. Since these studies are mostly based on proxy records that reflect a mixed signal of temperature and monsoon precipitation, it remains unclear whether warming has followed the same spatial and temporal evolution as EASM precipitation, or that EASM precipitation shows an increasingly delayed response to atmospheric warming towards the northwest.

Hence, we here assess the spatial evolution of warming over the last deglaciation by generating six quantitative temperature records based on soil bacterial membrane lipids (so-called 'brGDGTs') stored in loess-paleosol sequences along N-S and W-E transects across the CLP. Our records reflect a decrease in absolute temperatures from the SE to the NW, but the amplitude of deglacial warming increases from ~5 °C in Bailu in the SE to ~15 °C in Guojiapan in the NW of the CLP. Most importantly, the onset of warming in the NW lags that in the SE by up to 15 kyr, but overall leads changes in magnetic susceptibility in the same loess-paleosol sequence. This suggests that warming has followed the same spatial pattern as EASM precipitation, albeit offset in time. Presumably, warming first contributed to the waning of Northern Hemisphere ice sheets, after which the Siberian High could migrate north, allowing the EASM to gradually penetrate further inland towards the northwestern CLP.

Luminescence dated loess-palaeosol sequences in the eastern Carpathian Basin reveal variable Holocene climate

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Loess-palaeosol sequences (LPS) and loess like sediments are considered as some of the most significant terrestrial archives of climatic change and past atmospheric mineral dust activity. While these LPS have been widely used to investigate the immense climate disruptions of the last glacial period, relatively little attention has been directed toward the climate variability during the Holocene. The main reasons for this was the lack of LPS with a well-preserved Holocene record and more importantly, that the Holocene is generally considered a period of climatic stability. Loess in north-eastern Serbia drapes the westward slopes of the Carpathian-Balkan Mountain chain and provide a useful insight into climate dynamics, but until recently remained almost unexplored. Latest studies conducted on the Kisiljevo LPS and surrounding sites revealed that these LPS preserve some of the most extensive loess accumulations during the Holocene and MIS 2 thus far discovered in this part of Europe. This implies that the atmospheric mineral dust activity in this region during the last c. 12 ka was considerably higher than previously assumed and that the Holocene climate variations may have been larger and more frequent than current climate models suggest. To further investigate this, high-resolution, independent age models of additional well preserved Holocene loess are needed. Here we present initial OSL chronologies from LPS in north-eastern and eastern Serbia at a resolution capable of detecting even slight dust accumulation variations and hiatuses. Our dataset incorporates high-resolution Bayesian modelled chronostratigraphies with dust mass accumulation rates, grain size and magnetic susceptibility analyses.

Age-depth models indicate extremely high rates of dust accumulation during the Holocene; this has not been detected elsewhere in the wider region. The observed increase in atmospheric dust concentrations also generally coincides with at least one major Holocene cooling event for the Northern Hemisphere (9000–8000 cal. a. B.P). There were obviously phases of colder and drier climate during the Holocene which allowed a higher atmospheric dust flux and high accumulation rates in the eastern Carpathian Basin.

High resolution luminescence dating of the Süttő loess-paleosol sequence (MIS 6-2), Hungary: age depth model and mass accumulation rates

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Loess-paleosol sequences are among the most important and detailed terrestrial records of local/regional climate and environmental changes during the Pleistocene. The Carpathian Basin offers a unique opportunity to investigate temporal and spatial variations in dust accumulation, since 20-25% of its area is covered by loess with considerable thickness (80-90 m at max).

High-resolution numerical ages are available for some loess sections across the northern hemisphere (Jingbian, Sanbahuo, Toshan, Dunaszekcső) making it possible to develop reliable age-depth models and calculate precise mass accumulation rates (MARs), which are important input data of paleoclimate models. However, the mentioned chronologies and derived MARs are mostly limited to around 50 ka, as they are based on radiocarbon and/or quartz luminescence ages. In this project, more than 130 luminescence and some radiocarbon samples were collected in 2020-21 to investigate the 20 m thick loess-paleosol profile at Süttő, located in the northern part of the Carpathian Basin. A systematic sampling for porosity/density measurements was also carried out beyond the luminescence sampling.

The luminescence ages are calculated using the Optically Stimulated Luminescence signal of quartz for the younger part of the sequence and the post-Infrared IRSL signal of polymineral fine-grains for the >50 ka part of the sequence. The samples were collected from every 20 cm. All luminescence tests and measurements were carried out on primary samples. Secondary samples were measured using a shortened measurement routine to save measurement time thereby optimizing the use of resources.

Age-depth modelling is carried out using an R-package specifically developed for the Bayesian and inverse modelling of luminescence ages. Based on the constructed age-depth models and the already available datasets MARs were calculated for each MI stages.

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Late Pleistocene End-member Analysis and Its Environmental Significance on Grain Size of Loess in Central Shandong Mountainous region,China

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As the product of dust transport and accumulation under the specific environment of Quaternary, Chinese loess is an important carrier to study the evolution information of Quaternary monsoon circulation and sedimentary environment. Loess Plateau is the most continuous and thick loess area in China, which has been widely concerned by scholars at home and abroad. In recent years, aeolian deposits outside the Loess Plateau have gradually become a hot research content. There are many loess deposits along the Muwen River in Hulinqian, and many ancient human activities have been found in the river terrace landform of the region. Therefore, the study of loess strata in the region has important implications for understanding the evolution of climate and environment for ancient human activities.In this study, the parameterized end-member modelling analysis of grain-size distributions is used to discuss the sedimentary characteristics, transport dynamics and environmental significance for a loess section in Hulinqian, Shandong Province.The results indicate that (1)The OSL ages of the Hulinqian section ranged from 2.26 to 77.91ka, suggesting that sediments were mostly deposited since the late Pleistocene.(2)The grain-size components of the sediments in this section were divided into four end members: EM1(first mode grain size 0.56μm) represents the mixed clay component of pedogenesis and transported sediment；EM2 (first mode grain size 6.32μm) represents the fine silt component transported by the high-level westerly wind over long distance. EM3 (first mode grain size 17.83μm) represents material that settles as floating dust; EM4(first mode grain size 35.57μm) represents the silt component transported via low-level suspension by the local wind systems.(3) According to the climatic proxies such as the grain-size end-member content, magnetic susceptibility and chromaticity, combined with the results of OSL, this effectively indicated the stage change and differences of the sedimentary environment in the Hulinqian section since the late Pleistocene and reflected the regional response to global climate change.

Loess, sand, wind and Ice: a Midwestern United States Late Wisconsin (MIS2) polygenetic Landscape and the formation of Paha

Mr. Phillip Kerr [1]

1. *Iowa Geological Survey*

Indicators of the long-term activity of the jet stream during the Last Glacial Maximum are found in Eastern Iowa, in the Midwest United States. This area is distinctive landform region called the Iowa Erosion Surface (IES) which formed during the Last Glacial Maximum, but not covered by ice during the Late Wisconsin (MIS 2) and has little to no loess cover. Surrounding regions, however, can have 10-20m of Peoria Formation loess on the uplands. Perplexingly, the IES also contains unique linear hills topped with 10m of loess, called paha. Their formation, timing, and relationship with the surrounding loess-free landscape has been debated for over a century.

To address this quandary, this study created a new polygenetic landscape framework using combination of extensive landform mapping, field data, and chronologic ages. Features mapped include dunes, paha, deflation troughs, linear loess-covered hillslopes, outwash-filled valleys, glacial margins, paleo-drainages, and periglacial erosional forms such as retrogressive thermokarst slump scars. Features formed from loess such as paha have an exceptionally uniform linear geometry which wind direction indicators found in dunes. The landforms indicate a uniform paleo-wind direction of ~300˚, west-northwest. AMS radiocarbon dating was conducted on organic materials collected in eolian sediments, paleosols, and debris flow deposits. Ages from charcoal collected from the in the Farmdale Geosol indicate the landscape was stable until ~27ka. Plant and wood collected from debris-filled valleys return ages of ~26ka, which indicate the start of widescale periglacial destabilization. However, radiocarbon ages from Succinea snail shells collected at the base of unleached loess indicate the onset of rapid loess deposition starts after periglacial erosion. Eolian sand was also active across the landscape and was able to be transported via the intense winds and flat topography due to periglacial erosion. which deflated loess except where topographic barriers blocked saltating sand. Paha formed because of this process. Loess was able to accumulate where there was an upwind impediment to deflating sand. The uniformity of these eolian features is likely due to the jet stream being locked onto the glacial margin during portions of the Last Glacial Maximum.

Magnetic susceptibility properties in loess- paleosol sequences over Eurasia

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Because the magnetic susceptibilities of sediments are reported in various dimensions, and can be normalized to mass or volume, it is challenging to find truly compatible data from a suite of wide-spread localities. In this contribution, we compare magnetic enhancement as derived from magnetic susceptibility, and its frequency dependence from a variety of localities from western Europe to Asia. All data is measured with the same instrumentation and settings, providing true compatibility. Our comparison shows that full interglacial soils do not always reach the same degree of enhancement as well as different background susceptibilities which imply differences in dust sources. Furthermore, a suite of processes are acting on the magnetic properties, including magnetic enhancement as derived from magnetic susceptibility as well as wind vigor, and signal depletion by predominant occurrence of diamagnetic minerals.

We will present and discuss the result of a cluster analysis, and evaluate the usefulness of such an approach to our datasets. Further, we will exemplary explore the relationship between magnetic enhancement and (post-depositional) grain size variations.

Interplay pattern of monsoon and Westerlies in hyper-arid Asian interior since last deglaciation

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Establishing the relationships between the behavior of monsoonal circulation and the behavior of the Westerlies in arid, continental climates represents an important problem of paleoclimatology, with significance for projecting arid-region water availability in a warming world. Using newly collected proxies in the Tarim Basin (TB) of interior Asia, together transient model simulations, we propose that a higher occurrence of rainstorms and an enhanced aridity coexisted in TB and surrounding mountains during the warmer time intervals over the past 15 kyrs. Insolation-gradient-driven weakening of the Northern Hemisphere summer monsoon was accompanied by an intensification and a southward displacement of the boreal Westerlies, leading to decreasing summer rainstorm events in basin and moistening the high-altitude mountains. These findings help refine our understanding of the effects of Westerlies and summer monsoon on the hyper-arid Asian interior hydroclimate and provide profound implications for understanding the cultural communications between east and west Asian ethnic groups.

Clay mineralogy of the Stari Slankamen (Serbia) loess-paleosol sequence during the last glacial cycle — Implications for dust provenance and interglacial climate

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Clay minerals in loess-paleosol sequences carry important information on dust source and the regional paleoenvironments. However, relatively little is known about the origin and temporal variations of clay minerals in these deposits in the Serbian part of the Carpathian Basin and their paleoclimatic implications. Here we present the results of high-resolution XRD clay mineral analysis of the Stari Slankamen loess-paleosol sequence through the last glacial cycle, at a 10 cm-interval in paleosol and a 20 cm–interval in loess horizons.
The results show that illite (range of 27–63%, average of 42%) and smectite (range of 9–49%, average of 32%) dominate the clay fraction, while chlorite (range of 12–22%, average of 17%) and kaolinite (range of 6–13%, average of 9%) are less abundant for the 12.70-m thick section. The roughly constant composition of the clay minerals within the loess unit and most of the paleosol suggests that the clay minerals are of detrital origin and that pedogenic transformation has only occurred in the lower part of paleosol V-S1, which corresponds to the climatic optimum of Marine Isotope Stage (MIS) 5e. The smectite-rich characteristic of the glacial loess provides a diagnostic indicator for confirming local sources for the Carpathian Basin loess deposits, and that these sources made little contribution to the dust deposited in Greenland during the last glacial. The first application of illite crystallinity and the chlorite ratio to the Carpathian Basin loess-paleosol sequence suggests that they are more sensitive indicators than the clay mineral proxies previously used in European loess studies. The enhanced precipitation during MIS 5e indicated by the new proxies and the transformation of clay mineral potentially provide new insights into understanding the regional climatic response to future global warming.
Keywords: Loess, Carpathian Basin, Clay mineralogy, Last glacial cycle, Provenance

Loess in Equatorial Peru

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Loess occurs today in mid-high latitudes owing to silt generation via glacial grinding, and in subtropical deserts owing to non-glacial mechanisms of silt formation. But global maps depict an absence of loess in equatorial regions. Here we report particle-size and provenance data on inferred loess and associated sediments from the Cordillera Blanca, Peru, and discuss implications for loess formation.

The Cordillera Blanca forms a high-altitude (peaks >6 km) mountain range trending north-northwest in southern equatorial Peru (~8-10^{o}S), and is the glaciated footwall of a large detachment composed predominantly of the Cordillera Blanca batholith (12-5 Ma). Along the western slope of the range, glacial valleys incise transversely every 5-10 km and join the Rio Santa, which flows axially along the range before turning westward, ultimately debouching into the Pacific Ocean.

We sampled sediment from proglacial lakes, glacial moraines and eolian mantles of glacial valleys near and north of Huaraz, Peru, and from floodplain and loess of the Rio Santa along its course. Glacial sediment here is derived mostly from the relatively coarse-grained Cordillera Blanca granitoids. Sediment samples were processed for removal of organic and carbonate material before particle-size analysis of the <2000 µm fraction using a Malvern Mastersizer 3000 LPSA. Resulting PSD modes: glacial moraines: 40, 100 µm; proglacial lakes: ~18, 49 µm; eolian mantle at the head of a glacial valley: 40 µm; Rio Santo floodplain:~35-60 µm; loess: ~25 µm. Detrital zircon geochronology for the moraine exhibits a primary mode at 12 Ma, the same as the loess collected ~80 km downstream (north), although the loess includes a number of insignificant older age populations. The predominant age population of the moraine and loess match (12 Ma), indicating connectivity between proximal and distal deposits in this system. Older grains in the loess indicate downstream contributions from other sources along the Rio Santa system.

Glacial processes associated with this system are producing abundant fine-grained sediment with the potential to form loess, although few suitable areas for deflation and traps occur owing to the extraordinarily high relief.

Precipitation-dissolution dynamics of calcite and Silicate in the Tiefer See, Northeastern Germany

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The sensitivity of lakes to changes in environmental conditions make them excellent hydroclimatic recorders. However, the transfer of environmental signals into the lacustrine record is highly complex, involving diverse hydroclimatic-limnologic-sedimentologic processes on different time scales. To distinguish and quantify signal transfer processes in lakes, we developed a state of the art, intensive meteorological-limnological-sedimentological monitoring set-up at the Tiefer See, Northeastern Germany. Previous studies show that deposition rates peak during the spring-summer due to the spring diatoms bloom (March-May) followed by deposition (May-September). Here we follow variations in the Si, Ca and alkalinity concentrations along the water column as indicators for silicate and deposition/dissolution. These elements exhibit a seasonal cyclic behavior that corresponds the observed accumulation of silicate and in the sediment traps. During the spring-summer, the depleting concentration at the upper water column (depths <12 m), from 1.5 to 0.1 mg/l is concurrent with the increasing concentration at the bottom water column, from 1.5 to 2.5 mg/l. This indicates that diatoms formation during the spring is limited to the upper part of the water column. As diatoms settle to the lake floor, some are rapidly dissolved there. This is supported by the sediment trap data, showing that at most springs the diatoms flux at the shallow trap is larger than in the deep trap. The concentration shows a depletion in the epilimnion from ~85 to ~70 mg/l, a later smaller depletion in the metalimnion, from ~85 to ~75 mg/l and a more or less constant hypolimnion concentrations, ~85 mg/l. This indicates that form at the upper water column, following the consumption by the diatoms bloom and increasing pH, however, it does not dissolve at the hypolimnion. The degree of saturation of and silicate along the water column support the presented dynamics as is supersaturated ($0.8<\Omega<7.2$) at the hypolimnion or only slightly undersaturated, while silica is highly undersaturated ($0.01<\Omega<0.7$) at the hypolimnion throughout the entire year. These insights contribute to the understanding of and cycles in the lake and is crucial for the understanding of sediment distribution in lakes.

Pliocene-Pleistocene Paleohydrological reconstruction of the Tropical Andes of Colombia.

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The Pliocene, from 5 to ~2.6 million years ago (Ma), is the last epoch when Earth's mean temperature was ~2.5-4°C warmer than today, and CO2 concentrations may have been higher than preindustrial levels. Although Pliocene warmth is well-know, there is a scarcity of Pliocene-Pleistocene records of terrestrial climatic and environmental change, particularly in the tropics, compared to marine records of mid- to high latitude change. This has resulted in considerable disagreement about the controls on tropical rainfall and temperature changes and uncertainty in future climate projections for this region. Whereas climate models generally predict rainfall increased in wet regions and decreased in dry regions in the Pliocene, existing proxy records indicate many discrepancies with these predictions. The Sabana de Bogotá in the Eastern Cordillera of Colombia offers unique sedimentary archives from the tropics (~4ºN), including sediment from an extinct lake preserved in the Funza-II core that dates to the late Pliocene. We measured hydrogen-isotopic composition of sedimentary plant waxes, C_{29} and C_{31}, along the Funza-II core to reconstruct past hydrological variability in the Sabana de Bogotá during the Pliocene-Pleistocene. We paired analyses of the hydrogen isotopic composition of terrestrial leaf waxes to reconstruct hydrological variability with branched glycerol dialkyl glycerol tetraethers (brGDGTs)-based temperature estimates that show that Pliocene temperatures were ~2°C warmer than mid-late Pleistocene temperatures. The plant wax isotope data test whether Pliocene warmth corresponds to a wetter climate than the mid-late Pleistocene.

Plio-Quaternary speleogenetic evolution of the Loza cave system based on the sedimentological record (Slavinski ravnik, W Slovenia)

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There are several contact karst areas in the NW part of the Dinaric karst. Slavinski ravnik corrosional plain is one of them, located south of the Postojna Basin, at the contact between impermeable flysch and karstified carbonates. As a result of multi-phase gradual regional tectonic uplift, climatic changes, erosion, and sedimentation, the evolution of the paragenetic Loza cave system can be observed. It consists of an intermittent ponor Markov spodmol, an epiphreatic cave Vodna jama v Lozi, an unroofed cave Brezstropa jama v Lozi, and several different bypass channels and shafts (e.g. Šimčev spodmol, Spodmol v Selški Lozi), representing side passages of the main unroofed cave. The multi-proxy approach allowed us to decipher the main factors of morphogenesis, speleogenesis, and changes in the karst underground hydrological zones in time. We studied several sedimentary sections of allogenic sediments, covered or intercalated with various speleothems, for mineralogical, paleontological, paleomagnetic, and U-series dating purposes. The mineral composition of allogenic sediments is consistent with transport from flysch of the Postojna Basin, which shows strong weathering at higher elevations. The paleomagnetic results of sampled sections reveal both normal and reverse polarities; some of them show an eastward counterclockwise rotation of more than 30°, which might represent the oldest allogenic sedimentation in this region. The distinct but contemporaneous sedimentation phases observed in the cave Šimčev spodmol reveal a more complex sedimentological and speleogenetic history than previously thought. Compared with previous research, the sedimentation of the Šimčev spodmol is older than the allogenic sedimentation in the Markov spodmol, while the formation of the unroofed cave Brezstropa jama v Lozi is the oldest. In summary, the location of the cave system, the interrelation of passages, and especially the sedimentological record show an evolution in all three karst hydrological zones reflecting the formation of the northern margin of the Slavinski ravnik corrosional plain within at least the last 5 million years. Therefore, the Loza cave system represents a unique, comprehensive study site with a complete speleogenetic evolution in a relatively small contact karst area, reflecting the Plio-Quaternary tectonic, climatic, and consequently hydrological and geomorphological changes of the karst system.

The Medieval Climate Anomaly in the Jakupica Massif (Republic of North Macedonia): evidence from Galubarnica cave

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Climatic change is having a fundamental role in driving the fate of water resource availability in southern Europe, Mediterranean and Balkan regions. These regions accumulate most of their annual precipitation via migratory storms during November–April, which are in part controlled by the structure of North Atlantic atmospheric variability that controls storm tracks and usually described by the North Atlantic Oscillation variability (NAO).

The stable isotope composition of speleothem calcite is considered an effective proxy to reconstruct (qualitatively) paleohydrological variability over these regions and potentially NAO dynamics during the Holocene, and to give insights on future climate evolution of the region.. We present isotopic data supported by U/Th data from two stalagmites collected in the Galubarnica Cave (Republic of North Macedonia), which cover about the last 2000 yr. The $\delta^{18}O$ shows its lowest values - indicating wetter conditions - between ca. 60 and 370 AD, interrupted by an interval of distinctively drier conditions between ca. 110-140 AD. The climate then progressively moved towards drier conditions with the driest interval of the whole record recorded from ca. 900 to ca. 1160 AD. This interval, which appears to be the expression of the Medieval Climate Anomaly (MCA) in the region, terminates abruptly after the 1200 AD with a multidecadal event of wetter conditions. Drier conditions during the MCA are also supported by lake-level investigations at Prespa Lake confirming the regional significance of the speleothem $\delta^{18}O$ record.

A matter of time: towards internal chronological frameworks for Plio-Pleistocene U-Pb dated flowstones from the Cradle of Humankind

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South Africa hosts some of the oldest hominid fossil remains, centered in the Cradle of Humankind. Climatic and environmental change played a pivotal role in the adaptation and diversification of our early prehuman relatives. However, the sedimentary and climatic archives in which their fossils are preserved are often discontinuous or difficult to date. Fortunately, calcite formations such as flowstones are ubiquitous across the Cradle caves and represent significantly wetter conditions in the past. They form the "golden standard" among palaeoclimatic archives as they can be precisely and accurately dated using U-Th and U-Pb dating techniques. It is, however, difficult to develop age-depth models for the Pliocene-Early Pleistocene U-Pb dated flowstones due to large and overlapping uncertainties of the individual U-Pb ages, hindering climatic proxy records to be anchored in time for this period. Therefore, here we focus on flowstones from just two carefully chosen cave sites, Gladysvale and Malapa. Two flowstone samples, GV01 and M9, are in macro appearance very similar to each other, even though they are from separate caves. Preliminary dating of GV01 shows it formed continuously between 344-337 ka (glacial maximum of MIS 10). The published U-Pb age for flowstone M9 is 2.026 ± 0.021 Ma[1]. This flowstone interval is of great significance as it forms the base of a sedimentary unit containing the fossil type specimens of *Australopithecus sediba*. We first establish an internal growth chronology for the younger U-Th dated GV01 flowstone by developing a tightly constrained age-depth model and using thin-section petrography, trace elements and visible layer counting. This record can then be used as a robust and well-understood analogue to build the first chronological framework for a high-resolution palaeoclimate proxy record for sample M9. This approach and model can eventually be applied to other, older Plio-Pleistocene Cradle flowstones, of which there are many.

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Pliocene to Holocene chronostratigraphy and paleoenvironmental records from Račiška Pečina cave sediments section (SW Slovenia)

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The sedimentary sequence of the Račiška pečina cave represents chronostratigraphy and climate records from the late Pliocene to the Holocene. It is one of the best preserved cave records of paleoenvironmental changes during the last 3.4 Ma. The studied sedimentary sequence is mainly characterized by the deposition of calcite flowstone layers in a huge speleothem dome with long hiatuses in a cave environment. The deposition of calcite layers was interrupted by sedimentation of clayey to silty sediments originated from the surface above the cave. The interlayered clastic clays contained significant and representative Early and Late Pleistocene fauna (e.g. *Ursus* ex gr. *Spelaeus* dated older than about 72 ka, *Apodemus* cf. *atavus*, *Borsodia* sp., *Pliomys* sp., and *Clethrionomys* cf. *glareolus*) and probably the first known fossil subterranean gastropod (i.e. *Zospeum* sp.). In the upper part of the section, a soot material from three layers was radiocarbon dated to about 11 ka, 9 ka, and 3 ka. A detailed chronology of the section was established based on magnetostratigraphy and oxygen isotope stratigraphy and correlated with paleontological, U-series, and radiocarbon results. The part of the sequence correlated by the OIS was deposited from about 3.4 Ma to about 80 ka (MIS Km3 to MIS 5). Throughout the whole sequence, the transition from Pliocene to Pleistocene at 2.59 Ma, the presence of the Olduvai subchron between 1.78-1.925 Ma, and the Matuyama/Brunhes geomagnetic field reversal at about 777 ka are well recorded by magnetostratigraphy. The section also contains important information on climate changes through time. Paleoenvironmental changes associated with changes in sediment type and disconformities in sedimentation are also well expressed by changing of stable isotope values, indicating changes in the main factors that controlled environmental conditions in the region. Before the long hiatus at 2.6-2.5 Ma, the oxygen record was mainly shaped by regional Mediterranean factors, but after discontinuity, the record becomes more similar to the LR04 stack, indicating an increased influence of Atlantic Ocean factors. The research of the section has shown that speleothem domes may contain a range of different paleoproxy data that cannot be collected in a single borehole or stalagmite.

Isotope and trace element records from Sırtlanini Cave (Aydın, west central Turkey): Implications for the Little Ice Age and Medieval Climate Anomaly during the Byzantine and Ottoman periods

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Anatolia (Turkey) served as a crossroad for early human migration and for the development of major empires such as the Hittites, Romans (Eastern provinces), Byzantines, and the Ottomans. It is geographically very susceptible to variations in available moisture, and as such climate has always had a major impact on the living patterns, organizations of its occupant societies, and agricultural productivity. An in-depth understanding of Holocene climate variability is thus critical to explore historical climate impacts in this spatially heterogenous region. Within this main objective, this study focuses on detailed mineralogical and geochemical (stable, radiogenic isotope and trace element) data sets obtained from a late Holocene stalagmite (SRT-5) from Sırtlanini Cave in western Turkey. Uranium-series age results reveal stalagmite growth between 0.111 ka and 1.825 ka with two possible hiatuses, corresponding to the Roman, Byzantine and Ottoman periods. Carbon and oxygen stable isotope profiles demonstrate substantial paleo-hydroclimatic variability through the Little Ice Age (LIA) and Medieval Climate Anomaly (MCA) between 900 and 1909 CE. These changes are comparable with documented drought and migration events in western Anatolia, primarily in the 19th century. The start of the LIA (~1400 CE) during the Ottoman rule becomes evident when a sudden decrease in growth rate is observed together with enrichments in stable isotopes ($\delta^{13}C$ and $\delta^{18}O$), clustering in Mg/Ca, Sr/Ca, Ti, Mn, Fe, Ni, and a marked increase in Hg at ~1500 CE. Although the Hg signature may reflect higher atmospheric Hg sourced from ancient mercury and/or gold-silver mining activities, trace element anomalies and increased Sr isotope ratios suggest elevated dust levels and prior calcite precipitations during the dry conditions of early LIA. Most metals (e.g., Pb, V) show similar variations starting from around 1250 CE (calculated variance of 57% using principal component analyses), pointing to a common environmental and/or geological factor effective in Sırtlanini Cave around this time. The need for further analyses (e.g., additional age and SEM studies) is recognized to investigate the uncertain periods of stalagmite growth and assess the possible influence of human activities in and around the cave.

Climate variability in the southwest of Europe during the beginning of the Middle Pleistocene based on flowstone records

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In southeastern Spain, there are a series of cavities of considerable extension generated by mass movements of carbonates on a metapelitic substrates. The speleothems generated in these cavities provide information about the past climate in this semiarid area and the geological times after the generation of these landslides. A flowstone speleothem was studied from a wall of Sima del Saliente (Almería province, SE Spain), a cavity formed in a deep fracture (164 m deep) opened as a consequence of these movements. The variations in the δ18O and δ13C curves registered two cold and arid periods, although most of the record was formed during a more humid and warmer period. The U-series dating show that the core of the flowstone developed from MIS16 to MIS14. According to the dating and the comparisons with marine isotopic curves, the speleothem was formed from 635 to 532 kyr BP. The petrographic analysis of the textures and habits of the flowstone, together with the isotopic analysis, allow us to precisely define the climatic events recognized in the Sima del Saliente speleothem record.

Oxygen isotope composition of speleothem between Northern and Southern Italy during the Younger Dryas

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The Younger Dryas (YD-12.9 to 11.7 ka), corresponding to GS1 in the Greenland ice record, was a period of rapid climate change occurring at the end of the Last Glacial Termination, with the strongest impacts apparent in the Northern Hemisphere (NH). Temperature over the Greenland Ice Sheet cooled by up to 10°C over periods of years to decades, and North Atlantic sea surface temperatures (SSTs) cooled by 1° to 7°C. Changes in the Atlantic Meridional Overturning Circulation, related to increased meltwater runoff from Greenland ice sheet, are believed to be a major contributor, causing also a reorganization in NH atmospheric circulation highlighted from Northern Europe temperature proxies and numerical simulations. The YD expression and timing in Southern Europe and the Mediterranean are still less explored, but their recognition is crucial to understand the intra-hemispheric propagation of abrupt high-latitudes changes. Here, we present a high-resolution speleothem stable isotope record from Bossea Cave (SW Italian Alps), covering the terminal part of the deglaciation and the Holocene onset. Across the 12.8 to 11.7 ka interval, the Bossea record shows an abrupt drop of $\delta^{18}O$ values. This suggests that changes in atmospheric condensation temperature were the main driver for the speleothem $\delta^{18}O$, with lower values related to cooling during the YD. The timing and pattern of this lowering of the $\delta^{18}O$ values agrees with increasing $\delta^{18}O$ values recorded by southern Italy speleothems, interpreted as the expression of drier conditions during this interval. This indicates the existence of a strong isotopic gradient across the Italian peninsula. The Bossea record provides additional evidence for a highly interconnected North Atlantic and Mediterranean climatic regime, with high-latitudes to European temperature changes coupled to Mediterranean hydrological fluctuations. It also highlights the existence of substantial differences in the same proxy at regional scale.

A speleothem record of climate variability in the southeastern Iberian Peninsula during the Roman period

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Previous studies of lake sediments defined the Iberian Roman Humid Period (IRHP, 2600–1600 cal yr BP) as the most humid phase of the last 4000 yr in southern Spain. However, an increasing number of high-resolution paleoclimatic records suggest that sharp climate changes, including phases of persistent droughts, may have occurred during the IRHP. Here we present a novel $\delta^{18}O/\delta^{13}C$ stalagmite record from El Saliente Cave (Almería), spanning from ~4500 to ~800 yr BP and focus our investigation on the IRHP. During the early-IRHP (2600 to 2000 yr BP), the stalagmite growth rate was up to 34 times higher than during the late-IRHP (2000 to 1600 yr BP), indicating that a higher water seepage and wetter conditions prevailed during the early-IRHP. The $\delta^{18}O/\delta^{13}C$ records largely agrees with the observed growth rate changes. The $\delta^{18}O$ series is interpreted here as indicative of variations in the $\delta^{18}O$ of rainfall and precipitation amount, as a response to changes in the precipitation regimen and the predominant source of humidity, while the $\delta^{13}C$ record reflects changes in the vegetal coverage over the cave. According to the $\delta^{18}O$ series, the wettest period of the record (lower $\delta^{18}O$ values) occurred between 2400 and 2300 yr BP. Subsequently, conditions became gradually more arid until 2170 yr BP (the lowest $\delta^{18}O$ values of the series). Afterwards, during the late-IRHP, the $\delta^{18}O$ stabilized to values ~1‰ lower than during the early-IRHP, as consequence of relatively drier climate condition. The $\delta^{13}C$ record indicate that a denser and probably arboreal-based vegetation prevailed between 2400 and 2300 yr BP, which rapidly changed to steep-type vegetation by ~2100 yr BP. The observed isotopic variability during the entire IRHP closely follows the changes in the paleo-NAO indexes. This demonstrates that the paleo-hydroclimatic patters in SE Iberia were largely dominated by the interconnection between the North-Atlantic and the Mediterranean atmospheric realms.

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Comparing the isotopic trend of two similar-looking Mediterranean stalagmites

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In the central Mediterranean area, speleothem records covering the Last Glacial period and Termination I are scarce. Recently, stalagmite SA1 from Sant'Angelo Cave (Apulia region, southern Italy) has provided a record of the hydroclimate variability for this period based on high-resolution $\delta^{18}O$ data. Chrono-stages such as Greenland stadial/interstadial 2, Bølling-Allerød warm event and Younger Dryas cold event, as well as the Holocene onset, were identified through marked $\delta^{18}O$ shifts that agree in their timing with NGRIP.
SA1 was deposited from ca. 40 to 10 ka, and shows peculiar macro-morphological characteristics, such as i) diagenetic features at the bottom; ii) opaque layers interrupting translucent brownish layers; iii) a net diameter enlargement towards its top; iv) changes in the orientation of the growth axis.
A stalagmite morphologically looking very much like SA1 (named SA201) was recently sampled. Both stalagmites were found broken (by earlier visitors) in the same cave chamber. After slicing, SA201 shows the same internal structure as SA1. Importantly, the bottom and top U-Th dates of SA201 indicate that it encompasses the same time interval, from ca. 40 to 10 ka. SA201 is currently being analyzed for oxygen and carbon stable isotopes, by applying the same resolution (0.2 mm) as for SA1.
This study intends to compare the isotopic trend of these two stalagmites which form one speleothem generation. As a first step, the stable isotope profile of SA201 will be visually correlated to SA1 in order to construct a provisional synthetic chronology. In a second step, this age model will be tested by additional U-Th analyses. This study will thus explore to what extent coeval and morphologically similar stalagmites record the same isotopic trend. If this replication test is successful, the reliability of paleoclimate proxy timeseries from Apulian Caves will be greatly strengthened. Additionally, the two stalagmites will serve as key samples for future high-resolution quantitative temperature reconstructions by using analytical approaches which require a fairly high amount of sample material (i.e. fluid inclusion analyses).

Stalagmite-inferred precipitation record from northern Italy for the past 800 years and split westerlies over Europe in the early Little Ice Age

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During the well-known "Little Ice Age" (LIA, ca. 1450–1850 C.E.), Europe experienced the coldest winters over the last ten thousand years. This interval was suggested to have been caused by major volcanic eruptions and periods of low solar activity. However, the detailed climate pattern in Europe remains unclear. By conducting high-precision radiometric U-Th dating and trace element analyses on a stalagmite collected from Bàsura Cave, northern Italy, the evolution of the westerly winds over the past 800 years in Europe and the Mediterranean realm was reconstructed. A comparison of the Bàsura record with previous published precipitation data shows that during the early LIA (1470–1610 C.E.) the westerly winds not only migrated southward, but also split into two branches away from mainland Europe. This strong decrease of moisture-delivering warm westerlies resulted in dry and cold winters in Europe. The splitting of the westerly winds could have been triggered by frequent high-pressure anomalies in northern Europe.

The speleological evolution of phereatic paleokarst of Ghar Kriz Cave, Jbel Chetlou (TellianTunisia).

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The geomorphological study conducted in the Ghar Kriz cave, which is located in Jbel Chetlou, illustrates a model of the speleogenic evolution of the endokarst system especially, in the Tell region of Tunisia. The Ghar Kriz cave in Jbel Chetlou represents a ” phreatic paleokarst ” known particularly in the Tell region of Tunisia. This géomorphological study of Ghar kriz cave is based on the speleological exploration of the cave. The visual observations and the collection of samples are crucial to analyse the karstic environment and conceptualize the scenario of cave’s speleogenic formation. The carried out samples, mainly carbonate deposits (stalagmite concretion) and fine deposits (silty clay) have made it possible to specify two main speleogenic phases.
The first phase represents, the phreatic phase of the cave probably belonging to the pre-middle Pleistocene , as inferred from the evidence observed in the walls and ceilings of the cave. This phase is characterized by the presence of the ceiling pockets, the irregular shape of the walls as well as the insoluble pariental edges. Those patterns indicate the phreatic origin of the cave.
The second phase is the dewatring phase of the cave that started from the Middle Pleistocene (478823 ± 21,457 years BP) and up to the present day. This phase produces two generations of stalagmite concretions. The first generation (C 1) that is recorded in the middle to upper Pleistocene (from 478823 ± 21,457 years BP to 53162 ± 349 years BP) and the second generation (C2) that lasted from 10131 ± 315 years BP to 181 ± 11years BP. The latters are associated with significant periods of collapse related to the mechanical readjustement of the cave ceilings and walls.

Keywords : Ghar Kriz cave - speleogenesis phases-forms- deposits

Modern-day relationships between δ18O of precipitation and drip waters in the Renella Cave (Apuan Alps, western Mediterranean): paleo-hydrological implications

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Speleothems are cave carbonate deposits that can be precisely dated and efficiently record past climatic and environmental conditions, mostly throughout measurements of oxygen and carbon stable isotopes. The $\delta^{18}O$ variability recorded in Mediterranean speleothems is generally attributed to variations in cave drip water $\delta^{18}O$ (and precipitation $\delta^{18}O$), which are driven by changes in the hydrological cycle including variations in precipitation amounts and atmospheric circulation systems. Therefore, the $\delta^{18}O$ of Mediterranean speleothems is commonly used as a proxy of paleo-precipitation and paleo-hydrological reconstruction. However, evapotranspiration occurring in the soil and epikarst can modify the drip water $\delta^{18}O$, as well as complex flow paths due to karst hydrology that determine the mixing and homogenization of precipitation over several months or years. Moreover, the rainfall seasonality may shift the drip water $\delta^{18}O$ values towards the $\delta^{18}O$ signal of the season with the highest infiltration. Hence, the characterization of cave drip waters is crucial to identify the drips that have a clear relationship with the climatic signal and to interpret speleothem paleoclimate records properly. Monitoring studies on the $\delta^{18}O$ of precipitation and drip waters provide an understanding of climatic processes that control the rainfall isotopic variability and the transfer of the isotopic signal to cave waters, thus yielding more confident interpretations of past climate from speleothem records. Here, we provide the results from a two-year monitoring of the Renella Cave, a small shallow cave in the Apuan Alps (western Mediterranean), to understand the modern-day relationship between $\delta^{18}O$ of precipitation and $\delta^{18}O$ of drip waters. We collected monthly precipitation samples above the cave and monthly-integrated samples of three different drips, in addition to hourly monitoring of cave temperature and relative humidity. We recognized two groundwater flow systems feeding drips with different degrees of mixing and homogenization of waters. $\delta^{18}O$ variability of two drips was in the range of measurement error, unlike the wide precipitation isotopic variability, indicating a well-mixed system of waters infiltrated over long periods. The mean $\delta^{18}O$ of drips was more like the amount-weighted precipitation $\delta^{18}O$ than recharge-weighted precipitation $\delta^{18}O$, indicating the speleothem $\delta^{18}O$ as a proxy of paleo-precipitation.

Climate variability in southern Croatia from the end of MIS 5 through the last glacial period recorded in stalagmites from Mljet Island caves

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This study presents oxygen (δ^{18}O) and carbon (δ^{13}C) stable isotope records of two U-Th dated stalagmites from Mljet Island caves in the southern part of the Croatian Adriatic. Speleothem MSM-1 from Mala špilja Cave recorded environmental changes during Marine Isotope Stage (MIS) 5 (119–101 ka and 91–81 ka BP), MIS 4 (60–54 ka BP), MIS 3 (43–35 ka BP). A short interval (18–13.5 ka BP) during the Last Glacial Maximum (MIS 2) is recorded in stalagmite VSM-1 from Velika špilja Cave. δ^{18}O and δ13C profiles display main climatic oscillations correlated within the age uncertainty with stadial–interstadial events recorded in North Greenland ice core (NGRIP) such as Dansgaard-Oeschger (DO) (25, 24, 17, 16, 15, 11, 10, 9, 8 and 7) and Heinrich event (HE) 1. The lowest δ18O (-7.02‰) and δ13C (-12.14‰) are recorded in speleothem VSM-1 during MIS 2. Speleothem MSM-1 recorded highest variations in both δ^{18}O and δ^{13}C during MIS 5. Consequently, this study confirms the assumption that changes in atmospheric and ocean circulation observed in Greenland and the North Atlantic during the last glacial, influenced the Mediterranean region and eastern Adriatic area. In addition, the timing of the VSM-1 deposition confirmed the hypothesis that during Last Glacial Maximum conditions in the Croatian part of the eastern Adriatic coast were favorable for the speleothem deposition.

Limited water availability during peak interglacials revealed by speleothem records from SE Spain

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The modern climate of southeastern Spain is characterised by a strong seasonality of precipitation, with annual rainfall totals usually not exceeding 300 mm. In addition, high summer temperatures lead to increased evapotranspiration, further limiting water availability. The combination of high temperatures and low precipitation amount will further enhance the threat of desertification in the future. Given the climate conditions, there is only a limited number of (high-resolution) speleothem records from this region. Cueva Victoria is one of the few caves with speleothem growth in SE Spain, and previous studies have revealed a high proxy sensitivity to past hydrological changes on millennial and orbital time scale. During the Holocene, there is limited growth of speleothems in Cueva Victoria and the near absence of modern calcite precipitates and active drip sites inside the cave highlights the sensitivity of this cave site to reconstruct past phases of limited water availability.

Here we present several flowstone and stalagmite records from Cueva Victoria covering Marine Isotope Stages (MIS) 11 – 5. Precise U-series dating shows growth during both glacial and interglacial periods, although speleothem growth is more prominent in interglacial phases. Interestingly, interglacial maxima do not show the most favorable conditions for speleothem growth, as the growth rate is significantly reduced. This change in growth rate is interpreted as limited water availability in Cueva Victoria due to increased evapotranspiration. Other proxy data, including initial ($^{234}U/^{238}U$) activity ratios, stable isotopes of carbon, oxygen and calcium, as well as $^{87}Sr/^{86}Sr$ and trace elements, confirm this interpretation. For example, in all speleothem samples examined, the highest Sr and Mg concentrations were found during MIS 11c, 9e, 7e and 5e, due to increased prior calcite precipitation (PCP). In contrast, MIS 11a and 9c proxy data show increased growth rates and generally wetter conditions. This shows, that during peak interglacials, speleothem growth was hampered by limited water availability similar to modern conditions. To better understand the underlying mechanisms, we will quantify the amount of PCP during different (peak) interglacials using Ca isotopes and aim to reconstruct the severity of droughts during the last 425 ka based on a multi-proxy approach.

Southwestern European temperature constrained by speleothem fluid inclusion water isotopes over the past 16,000 years

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Major and abrupt changes in the Atlantic Meridional Overturning Circulation (AMOC) during the last deglaciation in conjunction with latitudinal shifts of the polar jet stream had a major impact on the climate in the North Atlantic realm, including the Iberian Peninsula, a southern European region key to understanding Northern Hemisphere climate teleconnections. Recent studies used isotopic records of speleothems to reconstruct the climate history since the last deglaciation in northeastern Iberia (Bartolomé et al., 2015; Moreno et al., 2017; Bernal-Wormull et al., 2021, 2023; Pérez-Mejías et al., 2021). However, quantitative climate reconstructions for this region are still scarce. In this work, we present fluid inclusion water isotope data from several stalagmites obtained from two neighboring caves (Mendukilo and Ostolo) in the lowlands of Western Pyrenees. Combining these speleothems allows for the first time for this region to obtain a record of the isotopic composition of paleo-precipitation of the last 16,000 years with the main objective of quantifying major climate shifts on a regional scale.

The speleothem $\delta^{18}O$ and fluid inclusion water isotopes (δD) records follow closely the well-known hemispheric climate changes showing more negative values during GS-1 and H1, related to colder climates, while less negative values characterize GI-1 and the Early Holocene, pointing towards higher temperatures. The results indicate larger oscillations in the fluid inclusion isotopic composition during last deglaciation (ca. 16 to 11.7 ka BP) than during the Holocene (last 11.7 ka BP), as expected from calcite stable isotope and trace-element profiles. As an example, the dD shift at the GS2a-GI-1 boundary is 30 ‰, which would represent a warming by 8.5ºC if the modern T-rainfall isotope relationship is applied. During the Holocene, events such as the 8.2 ka are characterized by a dD amplitude of 10‰. This quantitative fluid inclusion-based paleotemperature record resembles Greenland air temperature and Mediterranean sea-surface temperature records and allows for the first time a continuous temperature reconstruction since the last deglaciation for continental southern Europe.

Pyrenean speleothems as Holocene archives of hydroclimate variability

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Recent hydroclimate studies on the Iberian Peninsula have shown a complex regional pattern in timing and intensity of climate change spanning the Holocene associated to multifaceted interactions between climate variability that characterizes the Atlantic Ocean region and hydroclimatic processes associated with the Mediterranean climate. Speleothems from caves located at different altitudes in the Pyrenees constitute an exceptional source of detailed paleoclimate information yet unexplored for the Holocene period. This study combines high-resolution stable isotopes and trace elements analyzed in a total of thirteen stalagmites from five different caves in Central Spanish Pyrenees which have a robust chronology constrained by U-Th dates and 14C bomb peak identification. Speleothem data are later compared with lacustrine and marine records from the Iberian Peninsula. Carbon isotopic profiles are very different among the caves and providing a single reconstruction is not possible. Still, the organization of the caves in terms of altitude is evident, with less negative d13C values in caves located at higher altitude or under barren rock than those located under a well-developed soil. Combination of d18O profiles using *Iscam* software indicates a good overlapping among speleothems allowing to reconstruct rainfall isotopic variability at a regional scale. Thus, the onset of the Holocene is marked by a change to more negative values with the most negative ones attained at ca 10 ka BP, when we consider the Climatic Optimum in terms of precipitation. Later, during the second part of the Greenlandian and first part of Northgrippian (ca. 9-5 ka) a slight trend towards less negative values is observed. However, the main change occurs during the Meghalayan (4.2-0 ka BP) with in general less negative values and, in particular, the observation of two clear episodes with indications of dry climatic conditions, one at the onset of the period (4-5 ka) and the other one later on (at 2-3 ka). With this work we aim providing new knowledge on Holocene climate in NE Iberia and integrate it with previous marine and terrestrial records in order to get a coherent regional picture.

Sources of cave CO2 at Milandre cave, Switzerland constrained through multipool analysis of 14C and δ13C.

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A detailed understanding of how carbon is cycled in karst environments is paramount to our knowledge of global carbon fluxes because karstic geology accounts for 15% of terrestrial lithology. However, the source and transportation pathway of subsurface CO_2 in karst systems is not well constrained. The classical cave carbon cycle model suggests that the dominant source of vadose CO_2 derives from the respiration of catchment soils. In contrast, several new studies have suggested the contribution comparatively older and deeper sources of cave CO_2.

During an ongoing two year monitoring campaign at Milandre cave, northern Switzerland, we evaluated the $^{14}CO_2$ and $\delta^{13}CO_2$ composition of the atmosphere in the cave catchment, catchment soil gas, well gas, and cave air. We found that the ^{14}C signature in cave gas samples is more depleted compared to soil and well gas. The $\delta^{13}C$ of cave and soil/well gas samples have similarly low $\delta^{13}C$ values, indicating a dominant contribution from biological respiration. This could either suggest a source of CO_2 from an aged deep reservoir contributing to the cave gas or substantial influence from degassing of ^{14}C fossil carbonate CO_2 from drip water. The effects of seasonality on cave ventilation dynamics can be observed in the ^{14}C and $\delta^{13}C$ of cave gas collected from two locations at opposing ends of the cave system. In addition, cave CO_2 ^{14}C and $\delta^{13}C$ from a high spatial resolution sample collection crossing the cave is presented. These results have implications for the understanding of the subterranean carbon cycle and the interpretation of speleothem carbon isotope records for paleoclimate studies.

Can we distinguish the vegetation and soil component of speleothem d13C?

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Carbon isotopes are measured alongside oxygen isotopes in every stalagmite record, but have been more complex to interpret because the influences of regional vegetation and climate are often difficult to distinguish from speleothem specific-in cave effects from degassing and prior calcite precipitation (PCP). The effect of PCP on carbon isotopes are simulated by increasingly sophisticated process models. Here, we present the feasibility, advantages, and disadvantages of using trace element ratios and $\delta^{44}Ca$ to remove the overprinting effect of PCP on measured $\delta^{13}C$ to infer the temporal variations in the initial

$\delta^{13}C$ of dripwater which are set by soil and epikarst processes. In 8 examined stalagmites, the most widely utilized PCP indicators Mg/Ca and $\delta^{44}Ca$ covary as expected, and mutually consistent estimates of f_{Ca}, fraction of initial Ca remaining at the deposition of the stalagmite layer, can be derived from fossil stalagmites even when initial dripwater composition cannot be sampled. Published estimates of the effective slope for the evolution of $\delta^{13}C$ during degassing and precipitation allow estimation of the initial $\delta^{13}C$, from the calculated fCa and measured $\delta^{13}C$ for each sample. We show that in coeval stalagmites from the same cave spanning the 94 to 82 ka interval, trends in calculated initial $\delta^{13}C$ are more similar than those in measured $\delta^{13}C$, and reveal a common positive anomaly in initial $\delta^{13}C$ during a stadial cooling event, as expected from the temperature response of vegetation and soil respiration rates. During deglaciations, the trend of greater respiration rates and higher soil CO_2 is captured in the calculated initial $\delta^{13}C$, despite the tendency of higher interglacial dripwater situation to favor more extensive PCP. These results suggest that the calculated initial $\delta^{13}C$ may be a more readily interpretable proxy variable in many climate settings, especially mid and high latitudes where temperature effects on soil and vegetation are significant and not necessarily coupled with changes in effective moisture and drip rate.

Deciphering climate variability by studying Late Pleistocene cave infillings. Case study: Muierilor Cave, Romania

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This study presents data on the complex evolution of the Muierilor Cave system, in the Romanian Carpathian Mountains during the Late Pleistocene. The research included paleontological excavations coupled with sedimentological and geomorphological studies and dated through a combination of U/Th, OSL, and radiocarbon techniques. Studied deposits includes fossil remains, speleothems, and cave sediments and encompass a time range between ~120 ka through Holocene. Within this period, we have identified several evolutive stages of the cave and a succession of paleofloods most likely related to regional climatic changes. As a result, a rich fossil deposit accumulated that includes Upper Pleistocene fauna typical for the MIS 3-2 suggesting that the Southern Carpathians may had constitute a glacial refugia for the LGM great mammals. The taphonomical study combined with dating of speleothems from stratigraphically-relevant positions indicate that significant sediment inflow in the underground occurred between *c.* 22.5-14.5 ka. This suggests a deglaciation on the southern slopes of the Southern Carpathians that occurred earlier than previously known.

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Implications of modern pollen records on bat guano to paleoecological studies in southeastern Amazonia

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The rich diversity of bat feeding habits, from species that feed on insects and arthropods to those that feed on fruits, nectar, and flowers, leads to ecological interactions potentially archived in guano deposits. However, although bat guano provides important records about the evolution of the landscape and vegetation around the caves, they are largely neglected in Brazil, especially in southeastern Amazonia where over 1,500 cavities have already been identified. Our study aims to evaluate the pollen signal of guano deposits preserved inside the caves in relation to the surrounding vegetation. For that, bat guano surface samples were collected in five different caves located within the Carajás National Forest and Campos Ferruginosos National Park, in southeastern Amazonia. Our pollen data reveal a high diversity of very well-preserved palynomorphs. The presence of evergreen and forest patches taxa such as Tapirira, Ceiba, Parkia, Caryocar villosum, Alchornea, and Solanum in the pollen assemblage is strongly indicative of the local and regional vegetation cover. The recovery of fern and fungal spores in the pollen assemblage also reflects the warm and humid climate conditions in this region. The pollen data recovered from bat guano reveal that cave deposits in Amazonia provide a reliable substrate to understand the modern pollen and vegetation relationship. Where heavy rainfall and soil erosion occur and there is a paucity of lake, wetland, and swamp habitats, bat guano deposits can naturally be applied as a baseline for paleoenvironment reconstruction and paleoecology studies at both local and regional scales.

Palaeoenvironmental significance of hiatuses in speleothems

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Speleothems are now widely studied since they are a reliable archive that provides unrivalled record of the past climate changes. However, the speleothems are densely punctuated by hiatuses whose true significance and palaeoenvironmental meaning remain poorly understood. The hiatuses can provide invaluable insights into the periods that are otherwise not archived in spelean carbonates. The study of modern corrosion of speleothems and hiatuses in speleothem sections is still being conducted to unravel the processes which led to hiatus formation. A literature review and the studies carried out so-far enable to group hiatuses in speleothems into four below-mentioned types.

1. Corrosion of speleothems manifested by dissolution features are straightforward indicators of a hiatus surface. Such a kind of hiatus is characterized by irregular relief of the dissolved surface, which may support the deposition of detrital sediments, commonly of residual character, in the irregular voids thus formed. Several environmental factors can cause such type of a hiatus namely: (i) a quick inflow of aggressive percolation of water from the epikarst zone during humid conditions, (ii) episodes of flooding by an underground river, (iii) activity of bats in caves, (iv) condensation corrosion.

2. The presence of a lamina rich in non-carbonate clastic material serves as a significant indicator of the hiatus in a speleothem. Renewal of speleothem growth over such a hiatus is manifested by the re-nucleation of calcite crystals. The deposition of non-carbonate clastics is not always associated with corrosion of older parts of a speleothem. The non-carbonate material associated with a hiatus may also contain soot from fires in caves resulting in black colouration of speleothems.

3. The hiatus associated with the cessation of crystallization, but without any destruction of the formerly originated speleothem is a subtle feature since the younger overgrowth is often of epitaxial type.

4. Mechanical disintegration of a speleothem. The hiatus surfaces are sharp and irregular; they discordantly cut the speleothem. The breakage of speleothems can result from various factors (e.g., seismic shock, frost weathering, instability of surface at which speleothems grew, human activity).

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A Late Holocene climatic record for the Southwestern USA based on perennial cave ice

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A handful of caves and lava tubes worldwide host perennial ice deposits, which are the lesser-investigated members of the *cryosphere.* These deposits occur at elevations well below those of mountain glaciers and in areas outside the permafrost climatic belt, where no surface glaciation exists. These settings make any of the ice deposits in caves or lava tubes particularly susceptible to the current warming trend, leading to the imminent loss of some untapped cryospheric paleoenvironmental archives. Here, we present the results of a paleoclimate study based on an ice deposit accumulated within a lava tube in El Malpais National Monument (western New Mexico). The ice core spans the period 3828.5 to 1001 cal BP and its chronology is based on ^{14}C-dated charcoal present in some ice layers and volcanic reference horizons identified by means of non-sea salt sulfate peaks. The 110-cm-long ice core exhibits oxygen isotopic (δ^{18}O) values varying from −11.78 to −3.54‰. These values are influenced by composition of summer and winter precipitation which, in turn, can be affected by the source of precipitation (Gulf of Mexico versus Pacific). Therefore, the isotopic signal transferred from the atmosphere into the cave ice enables us to trace what main climatic systems affected its accumulation. The wide oscillation of this proxy suggests that several large-scale atmospheric circulation patterns, such as ENSO, the Pacific/North American pattern, the location of the ITCZ, and the North American Monsoon, significantly influence the region. The latter plays a critical role in increasing the isotopic values, showing the strength of summer rainfall over the record, particularly for the intervals 3828.5 to 3600, 2900 to 2400 (especially on 2800 to 2680 and 2650 to 2570), and 1900 to 1700 cal BP. The ice core also provides evidence for periods of prolonged drought, documented by the presence of 5 layers containing charcoal pieces. These are the product of man-made fires that occurred within the lava tube and date back to ~1017, 1121, 1203, 1582, and 1776 cal BP. Prolonged droughts correspond to La Niña phases characterized by weak North American Monsoon; this is especially true for the two oldest events.

Key considerations in developing precisely dated uranium-thorium chronologies from speleothems

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A key strength of speleothem palaeoclimate records is the accurate and precise uranium-thorium chronologies that underpin them. Uranium-thorium age determinations can be made back to at least 500,000 years, with relative uncertainties typically smaller than 0.5% (2-sigma), reaching 0.1% (2-sigma) in state-of-the-art studies of the late Pleistocene. The ability to be both accurately and precisely dated, in combination with their multiple proxies, has positioned speleothems as a critical archive for constraining the timing of climate events such as Dansgaard-Oeschger events, the Younger Dryas and glacial terminations. However, there are a number of important considerations that arise in the process of developing speleothem uranium-thorium chronologies that can potentially affect both the precision and accuracy of the final chronology. These considerations include: selection of the dating sample location; correction of ages for initial thorium activity (^{230}Th/^{232}Th); outlier identification and resolution; sample depth uncertainty; and interpolation uncertainty in the age model algorithm used. There is currently little guidance in the literature on how to manage these issues. Here we run a number of simulations to explore the potential effects these factors have on the accuracy and precision of speleothem age models. We also identify a set of best practices for producing accurate and precise uranium-thorium based chronologies across climate events, within the constraints of limited age determinations.

Abrupt paleoenvironmental changes during the Terminal Classic Period (800–1000 AD), as indicated by speleothem data from the northern Yucatán Peninsula

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The causes for the political collapse of the Classic Maya civilization in Mesoamerica during the Terminal Classic Period (TCP, c. 800–1000 AD) are heavily debated and discussions include the impact of both natural (e.g., droughts) and social disasters (e.g., warfare and unsustainable economy). An increasing number of records from various paleoclimatic archives (e.g., lake sediments or speleothems) points to recurrent multi-year droughts that coincide with the end of monumental construction, abandonment of cities and political disintegration during that period.
Here we present a multi-tracer speleothem record from Áaktun Kóopo cave near Valladolid on the northern Yucatán Peninsula. High-precision ^{230}Th/U dating shows that this stalagmite grew during the last 1400 years. The stable isotope record (δ^{18}O and δ^{13}C values) has an average temporal resolution of 2–3 years per sample, while the laser ablation ICP-MS trace element record (e.g., Mg/Ca, U/Ca, …) reaches sub-annual resolution.
δ^{18}O values show pronounced variability on the inter-annual to sub-decadal scale and increase to peak values of around −4‰ during the TCP, which we interpret as a continuous increase in arid climatic conditions. Around 850–900 AD, i.e. during the TCP, speleothem U/Ca ratios and δ^{13}C values show a pronounced shift, indicating major changes in aquifer recharge and vegetation/soil system. δ^{13}C values drop from an average of −8‰ (~600–850 AD) to values of −11‰ (~900–1700 AD). This shift may have resulted from a change in the vegetation and soil zone above the cave due to an abandonment of the area and a subsequent return to natural tropical forest. In addition, U/Ca ratios increase by a factor of two in the following period (~900–1700 AD), which may be linked to increased soil activity during this time. Ongoing work includes the incorporation of other hydroclimate-sensitive trace elements such as Mg/Ca and Sr/Ca to disentangle local and regional hydrological processes, as well as radiocarbon analysis (dead carbon fraction) to constrain changes in soil turnover times and host rock dissolution. This speleothem record may thus allow to investigate the local and regional climatic forcing as well as the environmental response to the collapse of the Maya civilization on the northern Yucatán Peninsula.

Hydroclimate variability in the Caribbean during the Last Glacial Period

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We provide a speleothem record spanning 98.7-84.9 ka BP from western Cuba. During 85–87.6 and 90.2–93.1 ka BP, our record reveals two different periods of high $\delta^{18}O$ corresponding to dry and/or cold periods, coinciding with Heinrich events 8 and 9. (H8 and H9). Thus, we present the first proxy evidence of the local climatic response to H8 and H9 in the Caribbean. Intriguingly, H8 is more apparent than H9, which may represent a local reaction to lower temperatures in the North Atlantic resulting in a weak AMOC and less deep water formation, therefore a greater southward shift of the ITCZ. Our results supplement existing speleothem records from western Cuba, which combined offer a virtually continuous paleoclimate time-series covering the past 100 ka BP and indicate a persistent response to millennial-scale episodes as dry and/or colder conditions. A study of regional paleoclimate data indicates an anti-phased link between the Caribbean and South America, induced by the southward migration of the ITCZ during millennia-scale occurrences, which resulted in drier conditions in the Caribbean and a more robust South American Monsoon System.

The spatiotemporal extent of the Green Sahara: A multi-proxy speleothem record from NW Africa

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The Sahara Desert, one of the world's most hostile ecosystems, has seen times of increased precipitation during which prehistoric people were able to survive. As a result of the paucity of paleoclimate data, the date and moisture sources of the Green Sahara remain unknown. We report a multi-proxy ($\delta^{18}O$, $\delta^{13}C$, $\delta^{17}O$, and trace elements) climatic record from NW Africa based on speleothems. During MIS5a and the Early to Middle Holocene, our data reveal two Green Sahara eras. The constancy of paleoclimate records throughout North Africa illustrates the east-west breadth of the Green Sahara, while millennia-scale cooling episodes in the North Atlantic have repeatedly led to drier conditions. We show that an increase in winter precipitation coming from the west during MIS5a led to favourable climatic circumstances for human population survival. The dramatic climatic degradation and decrease in human population density in the Sahara during the transition from MIS5 to MIS4 are indicative of climate-driven dispersals of local populations, which may have had ramifications for migratory routes out of Africa.

Improving Heinrich 1 chronology through Iberian speleothems

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Past changes in the Atlantic meridional overturning circulation (AMOC) represent a meaningful test case for abrupt climate events, given the multiple cascading feedbacks in the involved climate components such as ice sheets, ocean currents and shifts in atmospheric patterns. Multiproxy data ($\delta^{13}C$, $\delta^{18}O$, trace elements) from the Northwest Iberian speleothem archive (NISA) have recently shown to be highly sensitive to changes in salinity and sea surface temperature in the North Atlantic. This archive has a) the advantage of featuring the North Atlantic as the only moisture source, and b) provides simultaneous records of temperature and salinity changes in a single specimen. However, speleothems provide irregular time series and changes in growth rates over time occur regularly. To quantify rates of centennial to millennial change in AMOC from these records – crucially needed for modelling – a focus needs to be on deriving accurate age models and associated age uncertainties. We present here thoughts and approaches from the proxy side, with first results from a case study covering Heinrich stadial 1. We compare the similarity of two NISA speleothems over this period featuring several abrupt changes in isotopes and trace elements, but also a relatively slow growth (2-10 µm). Because of the large sample size needed for U-Th dating, a decent amount of mixing between growth layers occurs, limiting the accuracy of the estimated rates of changes. We address this challenge by tailored new U-Th dating, based on confocal microscopic images and prior isotopic measurements to constrain the main transitions in more detail. Additionally, age model reliability is improved by detecting changes in growth rates through higher resolution ^{14}C measurements. For ^{14}C, we assess the radiocarbon reservoir effect through coupled U-Th and ^{14}C measurements. If present, fluorescent layers or trace element cycles are additionally used as floating chronologies, anchored by the U-Th dates.

High-elevation speleothems suggest close coupling between North Atlantic millennial-scale variability and Alpine glacier dynamics during Marine Isotope Stage 8

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Processes triggering abrupt climate transitions during glacial periods are still not fully understood. Most research has focused on the last glacial cycle, limiting our test bed for studying the occurrence and absence of millennial-scale variability and, thus, our understanding of these large-scale reorganisations of the climate system under different background conditions.

Here, we present new stalagmite oxygen and carbon data from high-elevation caves in central Switzerland covering the period from ~300 to 200 ka. We demonstrate that millennial-scale variability recorded by these speleothems is representative of Northern Hemisphere interstadial-stadial variability. We use isotope-enabled fully-coupled ocean-atmosphere model simulations to show that the $\delta^{18}O$ value of meteoric precipitation was higher by ~1 ‰ during interstadials compared to stadials. This agrees with interstadial-stadial amplitudes of the last glacial cycle recorded by stalagmites from other caves in the Alps and is likely the result of North Atlantic seawater $\delta^{18}O$ millennial-scale variability.

We find that the effect of prior carbonate precipitation (PCP) is superimposed on the meteoric $\delta^{18}O$ signal, amplifying the isotope signal captured by Alpine speleothems on interstadial-stadial timescales. We propose that PCP variability provides a new proxy for milllennial-scale dynamics of warm-based paleoglaciers above these caves.

Seasonal climate conditions during the Penultimate Interglacial-Glacial Periods as recorded in speleothems from midcontinent North America

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Terrestrial climate records that include the Penultimate Interglaciation (PIG) and Glaciation (PG) are rare, and often suffer from larger geochronological uncertainties. This temporal data gap is more apparent when considering seasonally resolved climate archives. The PIG and PG archives that do exist generally are from lower latitudes, and thus are not representative of the atmospheric and climatic conditions of midcontinents, particularly in North America. Here we produce a seasonally resolved record of PIG and PG climate in midcontinental North America by combining microscopic imaging and micro-scale oxygen isotope ($\delta^{18}O$) measurements by ion microprobe from two speleothems that grew at the Cave of the Mounds in southern Wisconsin (USA). This cave was proximal to the margin of the Laurentide Ice Sheet during the PG. Prior work at this location demonstrated an increase in winter precipitation during the late Holocene, but relatively dry winters during the Last Interglacial Period. We further investigate climate conditions at Cave of the Mounds by applying both high resolution measurements and isotope-enabled climate modeling to compare seasonal variations in $\delta^{18}O$ during the PIG and the PG to resolve changing seasonality across climate mean states.

High resolution hyperspectral and discrete analysis of Adamello glacier ice-core sections from the ADA270 drilling project

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Paleoclimatic information recorded in polar and mountain glaciers are very important to study climate and environmental changes, telling a story about the ancient past and the ongoing cryosphere response to the anthropogenic impact. In this contest, a new high spatial resolution ice-core analysis has been done using a hyperspectral system, which allows to detect ice characteristics related to paleoclimatic information in a new non-destructive way. This improves the accuracy of measurements and the preservation of samples. The hyperspectral analysis has been applied on sections from the ADA270 ice core project, drilled in 2021 at the Adamello-Mandrone glacial group (Pian di Neve, Eastern Alps, Italy). The optical method acquires reflectance images collecting spectral radiance in 840 bands in visible and NIR wavelengths (400-1000 nm). Different optical descriptors have been computed from all reflectance spectra to measure variations due to ice features and impurities encloses in ice layers. In particular, we considered the surface albedo and two spectral indices: Snow Darkening Index (SDI) and Impurity Index (II). From such descriptors continuous records along the core, in particular Albedo and SDI, samples are accurately selected and melted to make a discrete analysis with a Coulter Counter Beckman Multisizer 4e to make a calibration. Analyzed features are ice lenses, visible air bubbles, medium supposed dust concentration and high content of visible materials. The discrete data have been matched with SDI values for all analyzed sections to apply a regression model. A calibrated curve for impurities concentration has been created, providing a very important tool to not systematically apply destructive measurements in all ice-core sections. For a depth ranging from 14 m to around 35 m, many high concentration peaks (to a maximum of 30-35 ppm) have been identified and associated to visible impurities layers. The rest of the curve, highlights concentrations lower than 5-6 ppm. We have great confidence that the analysis of ice trough hyperspectral imaging has a great potential for improving the analysis of ice cores, guaranteeing the preservation of pristine cryosphere records over time.

Evolution of the Critical Zone environment in the Forni Glacier forefield, European Alps: a top-down approach based on key environmental factors after glacier retreat

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Glacier retreat, mainly driven by the ongoing warming of the atmosphere, is globally exposing forefields that if found at lower altitudes than the species limits, rapidly undergo colonization from the ecosystem, thus giving place to pedogeneis and to the development of a fully functioning Critical Zone (CZ) environment. By assuming a top-down approach from the top of tree canopies to soil, we analysed key environmental factors from the air, forest, water, and soil sectors, for describing and reconstructing pace and timings of the environmental and landscape changes occurred in the Forni Glacier forefield since the end of the Little Ice Age. The most evident landscape change is the forest growth and trees advance in the forefield: here trees taller than 2m high form a Glacier Forefield Treeline (GFT). Below and behind the GFT, a fully functioning Critical Zone (CZ) environment exists. Here, the lag time between surface exposure after glacier retreat and the successful tree establishment (i.e. the trees' minimum ecesis interval) reaches a median value of 38yr and generally shows decreasing values towards the glacier front. Above the GFT, in the proglacial area where an incipient CZ exists, the ecesis shows a median value of 8yr and reaches the minimum value of 1yr. The early stages of the CZ development in the proglacial area resulted strongly influenced by poor soil conditions and by the katabatic winds influencing the colonisation patterns of saplings and young trees. Soil moisture potential, assessed by means of a topographic wetness index, showed a dependence on past glacier positions up to the Last Glacial Maximum. In the valley floor the different moisture conditions were associated to type of flows and to different water isotopic signatures found in summer 2016 in the different geomorphological contexts of the CZ environment: running waters (δ^2H = -36.17‰ and δ^{18}O = -4.74‰ wrt. the local rain); alongside the stream (or in topographic depressions); in the valley floor, lateral valleys, concave slopes (δ^2H = +29.44‰ and δ^{18}O = +1.58‰ wrt. tlr.); in the reliefs, ridges, convex or steep slopes.

Assessing glacier surface reduction and recent climatic variations within small glacial catchments – The Fumo Valley case study (Southern Rhaetian Alps, Italy)

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The assessment of climate change impacts within small Alpine catchments is essential for evaluating specific mitigation responses, predisposing environmental conservation strategies and planning a sustainable watershed management. In this study, glacier surface reduction from Little Ice Age to present and recent climatic variations were assessed in the Fumo Valley (Adamello Group, Southern Rhaetian Alps, Italy), which is a natural protected area with a high scientific-cultural value providing several ecosystem and socio-economic services (e.g., water resources for hydroelectric power generation).

Sentinel-2 multispectral satellite images were used to elaborate a present-state glacier inventory through a combination of remote sensing techniques, which was compared to previous published glacier inventories in order to assess numerical and geometrical surface variations. Also, two temperature data series related to different thirty-years periods were analysed to assess air temperature variation.

The results highlight a total surface loss of 5.99 km^2 (-71.0%) from 1850 to 1958. Between 1958 and 2022 a total area reduction of 0.87 km^2 (-35.5%) has been observed, which is comparable to other studies carried out at national scales. However, a marked progression phase has been observed between 1958 and 1981 (+76.3%), which is partially imputable to the glacial readvance episode occurred between the 1970s and the 1980s in the European Alps. After this phase, glaciers have been declined by 63.4% (1981-2022), with an accelerated regression phase between 2015 and 2022 (i.e., higher annual rate of variation, formation of ice-contact lakes, tongue separation and severe glacier fragmentation). The mean annual air temperature rose of 0.6°C between 1971-2000 and 1991-2020 periods, with a greater variation recorded for the mean annual maximum temperature (+1°C) if compared to the mean annual minimum temperature variation (+0.1°C) and a higher average temperature increase during spring and summer than in autumn and winter.

The results of this study can be interpreted as clear indicators of the impact of climatic change on local scale, highlighting the vulnerability of the study area with respect of the predicted future climatic scenarios. The climate change impacts are expected to intensify in the next decades, with significant implications for hydrological cycle, geomorphological hazards, landscape evolution and ecosystems.

Mediterranean to Hemispheric circulation influence on African mineral dust in ice cores of the European Alps

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Alpine ice core records are typically restricted to a regional scale and to relatively short timescales, allowing for detailed reconstructions of the European atmospheric and climatic history of the last centuries. Thanks to their position in the middle of Europe, ice cores drilled in the Alps have allowed to extensively investigate the impact of climatic changes and environmental activities on glaciochemistry and to assess the role of the Saharan mineral dust deposited in Southern Europe. The analyses highlight [gl1] a link between the atmospheric mineral dust records from the Colle del Lys ice core and the NAO variations. In fact, the two opposing Azores high and Icelandic low pressure centers not only control the trajectory of cyclones and therefore very long-range transports, but also the turbulence over North Africa, which determines the injection of dust into the atmosphere. The observed robust similarity between the Colle del Lys dust record and the Sahel Precipitation Anomaly indicates that there is a relationship between events in the Sahel, normally correlated to monsoons in the Indian Ocean, and dust transport events in the Mediterranean area. The correlation between the Sahel and the ENSO events has been already observed in the past, but this is the first time that it is possible to observe the effect of this mechanism in the European Alps.

A gradual-rather-than-abrupt mechanism caused the Mid-Pleistocene Transition

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The Mid-Pleistocene Transition (MPT, ~1.2-0.8 Ma) corresponds to a time interval when high amplitude ~100 ka glacial-interglacial cycles replaced the more subdued ~40 ka glacial-interglacial cycles. Whether the MPT was triggered by physical processes affecting the climate system at a specific time interval or more gradually over the course of the Pleistocene, is still an open question. In this study, we use an original approach based on conceptual modeling to identify the temporal structure of the MPT controlling factors. We present a new conceptual model which quantifies the global ice volume over the past 2 Ma. Our model switches between two states, a glaciation state and a deglaciation one, following a threshold mechanism related to the input parameters and the modelled ice volume itself.

Orbital-only, gradual and abrupt forcing hypotheses are tested using three simulations of our conceptual model in order to compare the relevance of each mechanism. The first one named the "ORB simulation", uses only orbital parameters as forcing inputs. In addition to accounting for the orbital forcing, the second simulation referred to as "ABR simulation" hereafter, includes a time-determined abrupt change that makes it more difficult afterwards to trigger a deglaciation. In the third simulation called "GRAD simulation", the initiation of a deglaciation is modulated by a continuous trend throughout the Pleistocene, while the orbital forcing is still considered too.

Our results show that the GRAD simulation best reproduces the change in frequency and amplitude of glacial-interglacial cycles observed during the MPT in the global ice volume reconstruction. Still, the good model-data comparison obtained using the ORB simulation suggests that the orbital forcing must be at least partly responsible for the MPT. In contrast, the results obtained with the ABR simulation are less relevant. Therefore, we propose that the MPT was due to the combination of the orbital forcing with an additional forcing characterized by a gradual change across the past 2 Ma. Our results support the hypothesis that a progressive decrease in atmospheric CO_2 concentrations throughout the Pleistocene played a key role in triggering the MPT.

Trace metal analysis of LEG 138 through the Pliocene-Pleistocene Transition

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Mineral dust aerosol is a main part of the climate system. Apart from sea salt, it is the most abundant primary aerosol and influences the radiative energy budget of the atmosphere. Aeolian mineral dust can intensify primary marine productivity and can be important for pedogenesis in distant areas. Trace metal can be a good proxy of the mineral dust deposition in the ocean. To understand the climate changes of the past it is required to have a precise reconstruction of the past atmospheric dust load and aeolian dust fluxes. Global climate change of the past 4 million years includes the end of the Pliocene warm period (5-3 Myr ago), the intensification of the Northern Hemisphere glaciation (2.75 Myr ago) and the emerge of the 100-kyr ice age cycles between 1.2 and 0.8 Ma ago. Therefore, Walker circulation seemed to be weaker during the warm Pliocene period.
Here, we present the results of the analysis of major trace metals of the IODP expedition LEG138, sites 848 to 854, a North (11.22ºN) – South (2.99ºS) transect through the meridian 110,00ºW situated at the Eastern Equatorial Pacific, of the last 4 million years. We analyze the data to infer changes in the atmospheric circulation on orbital scales, and to assess its meridional and zonal response during major climate transitions since the Pliocene.

Orbital forcing modulation of Indo-Pacific teleconnections during the past 2 million years

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Understanding the teleconnections between the Indian and Pacific oceans is key to better mitigating climatic impacts in the future. This often translates into studying the linkage between their dominant modes of interannual variability, respectively, the Indian Ocean Dipole (IOD) and El Niño-Southern Oscillation (ENSO). Positive phases of the IOD have been shown to correlate with positive phases of ENSO in present times, indicating a positive relationship between the two. A new type of positive IOD has been observed in recent decades that develops and terminates earlier than usual. In the past, some paleo records suggest that the Indian ocean's variability has changed with time, including the emergence of a so-called "equatorial mode." Also, results of the Holocene show that seasonal changes in the mean state resemble that of an IOD pattern in boreal autumn and that the ENSO-IOD teleconnection was affected by insolation forcing. Thus, several effects must be considered in these IOD-ENSO modulations, including seasonal changes that affect variability and teleconnections. Here, we use an accelerated transient Coupled General Circulation Model (CGCM) simulation covering the last 2 million years. This allows us to systematically identify how the changes in seasonality and the variation of the Asian monsoon alter the Indo-Pacific relationship. A focus will the on the analyses of the respective role of the atmospheric and oceanic bridges in shaping the equatorial sea surface temperature variations.

Characterizing AMOC multi-stability on glacial-interglacial time scales in an Earth system Model of Intermediate Complexity

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Variations of the Atlantic meridional overturning circulation (AMOC) are associated with Northern Hemisphere and global climatic shifts throughout the Quaternary. Hysteresis behaviour of the AMOC has been found in a hierachy of numerical circulation models, suggesting that tipping points might exist at which small perturbations can cause disproportionately large circulation and hence climatic changes. We discovered such tipping points in simulations with an intermediate complexity Earth system model, which is fast enough to study this non-linear behaviour systematically over entire glacial cycles with varying boundary conditions. The simulations revealed that the glacial AMOC is more stable than the interglacial one, and that several stable circulation states between the interglacial and glacial end-members exist. We present the circulation and sea ice patterns that characterise the stable circulation states between which the model alternates during a glacial cycle, and the influence of radiative forcing and orbital constellation on the timing of the shifts. Our simulations also show how the sudden circulation changes affect the regional and global climate. When increasing the radiative forcing beyond levels characteristic of Quaternary interglacials, the temporal variability of the interglacial AMOC increases but our model does not tip into another stable AMOC state.

Constrain the latest Pleistocene climate changes in Lanzarote deposit using calcretes and insect nests.

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Lanzarote, the easternmost island of the Canary Archipelago, represents an interesting study area to define the late Quaternary past climate changes occurred in extreme environments.

Mostly recent works have been addressed to palaeosoils formed as consequence of the dust storms coming from the close Sahara Desert; few have been addressed to calcretes (hardpan) and associated insect fossil nests -called "oothecae". Fossil nests are normally found in situ in 10 to 15 cm thick calcrete layers.

They occur in the NE part of the island where Late Quaternary deposit fill the El Jable plain. This is characterised by Late Pleistocene alluvial-fan systems merging into a wide central aeolian dunefield. Deposits are soils and calcretes alternated with dunes. The former are associated to humid-warm climate phases, the latter to cold-dry that alternate during the last 125 ky.

Our work concentrated on the upper 5 m thick sedimentary deposits of the Muñique quarry where 25-centimetre thick aeolian sandstones alternate with 1-5-centimetres thick hardpan interested by oothecae nests occur. Alluvial deposits appear at the bottom and top.

Eight *Hemycicla sp* samples for ^{14}C dating have been collected from different layers of hardpan and from the bottom and top deposits. The bottom has been dated at 30677 ± 319 cal BP, whereas the top at 12730±23.5 cal BP. Ages encompass the latest Marine Isotope Stages 3 (MIS3) and MIS2, specifically, the top matches the last-Pleistocene cold phase known as "Younger Dryas Stadial".

Although no precise information on the species is yet known, it is a fact that oothecae were built in situ by insects that did not dig in hard soils but only in soft, moist soils. It is reasonable to assume that they nested in a favourable humid environment.

The presence of hardpan with associated oothecae could be interpreted as damp moment as a result of climatic fluctuations in arid and semiarid regions. It is known that warm-cold high frequency millennium scale alternation known as Dansgaard-Oeschger (D-O) occurred during the last glacial time, particularly during the MIS3. We claim that hardpan and oothecae developed during the wet, humid phases associated with D-O stadial events.

Simulations reveal causes of inter-regional differences in Pliocene climatic periodicity

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The Pliocene Epoch (5.33-2.58 Ma) is a generally warmer interval with atmospheric CO_2 concentrations at or slightly above modern levels. Many geological records show dominant periodicities of about 41 ka and/or 21 ka during the Pliocene and have been ascribed to variations in Earth's orbital parameters. However, the mechanism for inter-regional differences in climatic cycle remains unclear. Here we perform four idealized experiments of orbit parameter's extremes, using a sophisticated coupled ocean–atmosphere global climate model, HadCM3. Our results show that changes in temperature induced by obliquity are large (>5 ℃) over high latitudes and relatively small (~0-2 ℃) over low latitudes, whereas those induced by precession or eccentricity are comparatively small (~0-3 ℃) worldwide. In contrast, precipitation changes driven by obliquity, precession, and eccentricity are all very small (~0.5 mm day^{-1}) over high latitudes, while over low latitudes, precession-induced changes in precipitation are dramatic (>2 mm day^{-1}) and those induced by obliquity or eccentricity are significant (~0-1 mm day^{-1}). These results indicate that the most notable effect of obliquity on climate occurs over high latitudes, whereas precession affects the climate mainly at low latitudes. Our findings reasonably explain not only the predominant 41 ka climatic periodicity at high latitudes and in marine oxygen isotope records regulated by high-latitude ice volume, but also the dominant 21 ka climatic cycle over low latitudes and the Mediterranean region.

Response of the Indian vegetation and monsoon changes during contrasting glacial periods: the MIS 14, 10, 6 and 4-2

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The Indian Summer Monsoon (ISM) appears particularly sensitive to ongoing climate change and its variability could have been a threat to freshwater availability, as well to sustainable agriculture in India in the near future. Despite intensification of monsoon rainfall suggested by the numerical models, severe droughts were recently recorded in India having dramatic consequences for the population and economy of the country. Hence, past ISM collapses have led to water scarcity and severe famines that were unfavorable to the long-term stability of societies such as for the Harrapan Civilization.

In order to better understand environmental changes and climatic mechanisms leading to catastrophic weak monsoon intervals in India, we aim at documenting the ISM variability during four glacial periods characterized by distinctive boundary conditions, namely the MIS 14 (~560-535 ka), 10 (~370-335 ka), 6 (~190-130 ka) and 4-2 (~80-20 ka). This study is based on an original approach that consists of pollen analysis of marine sediments drilled at IODP Site U1446, which gives an integrated image of the vegetation from the Mahanadi hydrological basin, and therefore of climate within the Indian core monsoon zone.

Low tropical tree percentages associated to grassland (Poaceae) expansions are recorded during all glacial maxima of the four studied periods revealing reduced hydrological cycle. In opposite, maximal development of tropical trees is recorded during the early MIS 14 when percentages of Combretaceae/Melatomataceae, *Glochidion*, *Mallotus*, *Hopea*/*Shorea* and *Tectona*, reach late Holocene values suggesting the highest ISM rainfall of the four glacial periods. A progressive change from a wooded savannah to an open environment composed by a varying proportion of grasslands, arid (Amaranthaceae and *Ephedra*) and semi-arid herbs (*Artemisia*) is also recorded during the MIS 10, 6 and 4-2. Therefore, a similar pattern displays in glacial vegetation records, in which a decrease in tropical trees and associated herb expansions, reflect a long-term ISM decrease during the four studied intervals. Herein, we suggest that the glacial aridification mirrors the global ice volume, although distinctive composition of the vegetation may also reveal a modulated response of the ISM to different factors such as sea-surface temperatures, ice-sheet distribution and/or orbital forcing (obliquity).

Bølling-Allerød warming as a part of climate internal self-oscillation

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Millennial-scale abrupt climate change events frequently occurred during the Late Pleistocene. Bølling/Allerød (B/A) event, which is the latest abrupt warming event, complicates understanding its occurrence due to the accompanying drastic climate background shift. Here we carried out a set of transient experiments during the B/A period under the PMIP4 protocol. The highlight is that a more realistic distribution of meltwater flux is applied in the experiments. We found that the intensity of the Atlantic Meridional overturning circulation (AMOC) is significantly modulated by the geographic distribution of freshwater injection. Considering only this distribution change without its temporal variation, our model shows a cold stadial climate during Heinrich Stadial 1 (HS1) and captures the B/A-like AMOC recovery. This B/A-like behavior is characterized by the self-oscillation of the AMOC and is mainly associated with a gradual change in the orbital parameters. The ice-sheet decline after the abrupt change attenuates the North Atlantic Deep Water (NADW) production, and the accelerated melting of the ice sheet after 14.5 ka (thousand calendar years before present) can develop this process, eventually moving the system out of this self-oscillation regime. The rise in atmospheric CO_2 does not offset this trend due to ice sheet retreat.

Comparing two similar extreme SST cooling events under different boundary conditions within MIS 8 and MIS 34 in the Iberian Margin

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In the last 1.5 Myr, the Earth was marked by abrupt climate instabilities on millennial time scales superimposed on the global variations in the ice volume. The timing, duration, and amplitude of major glacial-interglacial cycles have been modulated by changes in the Earth’s orbit. In particular, the Early Pleistocene symmetrical, low-amplitude, and high-frequency (41 ky obliquity) climate cycles were gradually replaced by the Middle Pleistocene asymmetrical, high-amplitude and low-frequency and quasi-periodic 100 ky cycles. However major climatic shifts, including glacial climate instabilities, are not explained by the orbital forcing theory. The long Sea surface Temperature record of IODP Site U1385 (the “Shackleton Site”) from southwestern Iberian Margin (IB-$U^{k'}_{37}$-SST) reveals a continuous millennially-resolved record for the last 1.5 Myr. Our results show warm interglacials over the entire record and a persistent feature of Millennial Climate Variability (MCV) mainly during glacial inceptions and deglaciations. During glacials, the MCV is punctuated by extreme cooling episodes after reaching the maximum ice volume and modulated by different boundary conditions. Here we present two strong stadial events that occurred under different orbital-induced forcings but with similar impacts on the surface water conditions at the North Atlantic mid-latitudes. The extreme climate events occurred in the mid-glacial of MIS 8 at ~270 ka and in the terminal stadial event of MIS 34 at ~1125 ka. Both episodes are marked by substantial changes in the surface-water density, forced by freshwater fluxes from the melting ice and changes in the deep-water ventilation, suggesting a similar trigger mechanism for these extreme cooling events in the Iberian Margin.

Synchronization theory of glacial-interglacial cycles in the Quaternary

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The dominant periodicity of glacial-interglacial cycles changed from 41 kiloyears (kyr) to roughly 100 kyr around 1 million years ago, which is called the Mid-Pleistocene Transition (MPT). Mechanisms generating these periodicities are still elusive. In this study we propose a synchronization theory of glacial cycles based on an Earth system model of intermediate complexity (CLIMBER-2), which is previously shown to simulate the MPT under a gradual decrease of volcanic CO2 outgassing rate and a shrinking area of regolith over the last three million years (Willeit et al. 2019). We show that the model exhibits self-sustained oscillations even in the absence of the astronomical forcing. Before the MPT, the glacial cycles synchronize with the 41-kyr obliquity cycles since the internal self-sustained oscillations have periodicity close to 41 kyr. After the MPT the time scale of internal oscillations becomes too long to follow every 41-kyr obliquity cycle, and the glacial cycles tend to synchronize with ~100-kyr eccentricity cycles which modulate the amplitude of climatic precession. The 41-kyr obliquity forcing however helps the synchronization with the ~100-kyr eccentricity cycles, through a nonlinear mechanism, which we call the vibration-enhanced synchronization.

Nature of cooling events on the southern Iberian margin points to extreme contraction of the North Atlantic's subtropical gyre during the early Pleistocene

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The Gulf of Cadiz on the western side of the Strait of Gibraltar marks the transitional zone between the North Atlantic and the Mediterranean Sea and is nowadays influenced by North Atlantic subtropical gyre waters. Studies on deep-sea cores from that region have shown that during the Heinrich events of the last glacial cycle colder surface waters penetrated into those southern mid-latitudes, but with reduced intensity. Making use of the centennial-scale paleoclimate records from IODP Site U1387 (36°48´N 7°43´W; 559 m water depth), which cover the early to middle Pleistocene interval of Marine Isotope Stage (MIS) 16 to MIS 52 (0.65 – 1.51 Ma), we are exploring the nature of cooling events during the Early to Middle Pleistocene transition (EMPT). Terminal stadial events during abrupt glacial/interglacial transitions, for example MIS 20/19, MIS 22/21, MIS 26/25 or MIS 48/47, recorded periods of extreme surface water cooling with annual sea-surface temperatures dropping below 15°C and the abundance of polar planktonic foraminifera species *N. pachyderma* increasing above 40% indicating the influx of subpolar surface waters into the southern mid-latitudes of the Northeast Atlantic. Those events can be related to disintegration of circum-North Atlantic continental ice sheets and their impact on the Atlantic Meridional Overturning Circulation (AMOC), similar to the impacts of Heinrich events. Additional stadial events with similar characteristics are also observed during early MIS 22, MIS 32 and MIS 38. The cooling on the Algarve margin during those EMPT events was, however, more intense than during Heinrich events 1 to 6 pointing to an extreme contraction of the North Atlantic's subtropical gyre during the EMPT. Duration of the cooling events varied between 1000 and 3000 years with a cumulation within MIS 22 with its two extended phases of extreme cooling. Prevalence of subtropical surface waters after the cooling event occurred generally within 1500 years, independent of the duration of the preceding cooling event, pointing to common processes leading to reestablishment of a strong AMOC. The IODP Site U1387 data reveals cooling events were a regular feature, but were, unexpectedly, more intense during the EMPT than during the late Pleistocene.

About the Mid-Brunhes interval and the role of the enigmatic coccolithophore Gephyrocapsa complex

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Noëlaerhabdaceae coccolithophores contributed to modulate the global carbon cycle by increasing carbonate export and burial rates due to recurrent enhanced production at low eccentricity scenarios with an ~ 400 kyr cyclicity during the Pleistocene. If this variability also entailed a change in the degree of coccolithophore calcification is unknown, but plausible since regulation in the carbon cycle at this scale necessarily involve deep changes in the state of ocean carbonate chemistry.

We analyzed the morphometries (size and mass) of the dominant *Gephyrocapsa* complex during the last eccentricity minimum episode 400 kyr ago, encompassing the Mid-Brunhes event, at a wide range of latitudinal environments across the North Atlantic region and the Mediterranean Sea. We capture an enhancement in *Gephyrocapsa* calcification coeval to high coccolithophore production lead by mid-sized *Gephyrocapsa* specimens. Analysis of diversity on the *Gephyrocapsa* complex allows us to determine an increased calcification expressed by an array of morphotypes at the different sites. Such widespread enhanced calcification across the *Gephyrocapsa* complex supports the existence of a common trigger for a higher degree of calcification of a range of *Gephyrocapsa* during the Mid-Brunhes. This feature is plausibly related to changes in seawater chemistry, e.g., HCO_3^- increase, that could explain the response of *Gephyrocapsa* calcification observed at all sites.

This perspective critically underscores that the nature of the stimulus mediating orbital forcing and long-term phytoplankton evolution or adaptation could be embellished by changes in seawater carbonate chemistry as a critical component.

A new reconstruction of CO2 oscillations through the study of marine fossil records during the mid-Pleistocene transition: Boron isotopes in planktonic Foraminifera as a tracer for paleo-pH and pCO2.

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The mid-Pleistocene transition (MPT) marked a fundamental change in the dominant period of Pleistocene glacial cycles, from 41-kyr to 100-kyr cycles. The reasons are yet unknown, since the transition occurred in the absence of any significant change in orbital forcing. Most hypotheses invoke a decreasing atmospheric carbon dioxide as the trigger of the MPT origin, even if it has not yet been fully demonstrated. To validate the suggestion that a long-term drawdown of atmospheric CO_2 was the main cause of the climate transition, we present a new high-resolution 1.9-myr atmospheric pCO_2 and sea surface temperature (SST°) reconstruction, based respectively on boron isotopic composition of *Trilobatus sacculifer* and Mg/Ca ratio in *Globigerinoides ruber* (s.s.).

Assessing large scale ecological responses to climatic change of Central Mediterranean area in the last 2000 years

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This PhD project is focused on the investigation of ecological dynamics across the Central Mediterranean area from a marine sedimentary record in Gulf of Gaeta. The geographic location and the semi-enclosed geometrical configuration of this area make it a vulnerable and sensitive region to modern and past climate changes. Multi-proxy approach is used to reconstruct the paleo-floral dynamics. This will enable relationships within and between ecosystems, as well as periods of stability and periods of changes. The method mainly consisted of the traditional pollen analysis - to reconstruct the vegetational palaeo-community, and chemical palynology – chemical signature of pollen – to reconstruct the past solar irradiance at the local, habitat scale. Specifically, ultraviolet radiation B which act as a biotic stressor and has the capacity to affect the eco and environmental systems.

Holocene hydroclimatic variability at the southern margin of the South American Monsoon System recorded by high-resolution sediment data from Lagoa Dourada, Brazil

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High-resolution and well-dated multidisciplinary data from the lacustrine sediment record of Lagoa Dourada (South Brazil) are presented and linked to long-term shifts in atmospheric circulation patterns of the Southern Hemisphere, which are mainly dependent on the spatial and temporal distribution of precipitation and climatologically controlled by the South American Monsoon System (SAMS).

Based on statistical analyses, four different sediment sources are characterized geochemically and related to lacustrine organic productivity, underground karst runoff, river flooding and cultural soil erosion. Thus, our multiproxy dataset provides a handle on lacustrine and catchment-related processes reflecting environmental responses to hydroclimatic fluctuations during the Holocene and to human activities.

Four distinctly different depositional conditions are determined: (1) Suspension fallout of fine-grained minerogenic particles transferred via fluvial activity during the Early Holocene and related to open grassland in the catchment area; (2) Activation of the karst hydrological system with deposition of sand layers indicating increased precipitation at the onset of the Middle Holocene; (3) Minerogenic sediments are replaced by organic deposition due to wetter climatic conditions with expansion of woodlands and release of nutrients due to enhanced pedogenesis during the Middle to Late Holocene; (4) Human-induced land-use changes caused destabilization of soils in the catchment area as well as cultural soil erosion since AD 1800.

The climatic development from a warm and dry Early Holocene to a warm and wet Middle and Late Holocene is in response to a strengthening of the SAMS. In addition to this general trend, our sediment record documents three of the two most prominent Holocene climatic events: the 8.2 ka event, the 4.2 ka event and the Little Ice Age. For Lagoa Dourada, these reflect several century-long increases in rainfall with complex responses of the environmental system – a result that favorably agrees with the climatic signal preserved by the speleothem record from Caverna Botuverá located ca. 250 km SSE of Lagoa Dourada.

Pollen preservation evidence from southern Patagonia (52°-54°S): Old methods, new insights into past changes in the Southern Hemisphere westerly Winds.

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The vegetation cover of Patagonia is tightly controlled by the distribution of precipitation delivered by the Southern Hemisphere westerly winds. Pollen analysis (palynology) continues to be the most successful technique for exploring vegetation history from which we can infer climate change. No other technique provides the two key elements of being able to synthesize the changing patterns of vegetation in space and time. However, pollen data (percentages, concentrations, and influx) can only tell part of the story and regional patterns may be blurred by local site-specific factors (microclimate, basin hydrology, catchment) and differing ecological responses to climate (extinction, migration, adaptation). Inferences based on palaeoecological data may be supported by other lines of evidence of environmental change; sediment chemistry, plant macrofossils, a range of other micro fossils (diatoms, testate amoebae) as depositional environments allow. Here we demonstrate the utility of analysing the preservation status of pollen grains which to-date has been largely overlooked in Patagonian pollen records. Well preserved pollen are indicative of quick deposition in a stable anaerobic environment, such as a wet peat bog or small closed lake basin. Deteriorated pollen occur along a spectrum from broken or crumpled (mechanical damage) pollen grains, which tend to reflect more energetic transport (fluvial or aeolian processes) to corroded and degraded (chemical damage) grains that indicate more aerobic conditions (i.e. reduced mire surface wetness) at the point of deposition. Here we describe a simplified (5 category) method with examples and present a synthesis of six Late glacial-Holocene pollen records obtained from peat bogs from Fuego-Patagonia (52°-54°S). Comparison with the pollen assemblage data highlights a high degree of resilience in the vegetation, particularly the dominant arboreal taxa of the subgenus *Nothofagus* (southern beech), which leads to asynchronous responses to climate change. Our evidence suggests chemical damage is a particularly sensitive indicator of changes in mire surface wetness from which changes in precipitation can be inferred. This evidence has important implications for understanding the nature and timing of changes in the Southern Hemisphere westerly winds in southern Patagonia during the Late glacial and Holocene.

Tree-ring δ18OTRC variations in South American Nothofagus species record common large-scale climatic signals

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Southernmost South America (SSA; 50-56°S) has recently experienced accelerated warming, decreased precipitation, reduced snow cover, and increased heat waves. These climate changes are related to variations in atmospheric circulation affecting SSA at different temporal scales. Since meteorological records are short with frequent gaps, long-term studies intended to properly identify changes in the dominant atmospheric circulation patterns in SSA are rare. Previous studies in SSA based on oxygen isotopes from tree-ring cellulose ($\delta^{18}O_{TRC}$) have shown the potential to extend local climate and atmospheric circulation records. Here, we studied two contrasting *Nothofagus* forests located in i) the deciduous *N. pumilio* forest in the transition to the steppe close to Punta Arenas (SKI site) and ii) the humid evergreen *N. betuloides* forest (NC site) in the Navarino Island. To investigate the potential for reconstructing past climate variability, $\delta^{18}O_{TRC}$ variations in tree rings from both species were compared over the last 60 years with local climates, as well as regional (Amundsen Sea Low, ASL) and hemispheric (Antarctic Oscillation, AAO) atmospheric patterns. The *N. betuloides* (NC) $\delta^{18}O_{TRC}$ variations showed an overall positive trend, indicating an isotopic enrichment during the last 60 years, whereas no trend was recorded in the *N. pumilio* (SKI) record. The strongest relationships with climate, which also showing the widest spatial representativeness, occurred for the NC chronology during the growing season (spring to austral summer) and extended spatially from mid to high latitudes. In contrast, the sensitivity of the SKI isotopic records was limited to summer months, and the spatial correlations were much more limited. In addition, the NC record showed greater potential for reconstructing local climate features such as soil water ($r = -0.76$), wind speed ($r = 0.69$) and precipitation ($r = -0.66$), as well as regional (ASL, $r = -0.80$) and hemispheric (AAO, $r = 0.77$) patterns of extratropical atmospheric circulation. Overall, weaker relationships between the isotopic *N. pumilio* record at SKI with local climate and large-scale circulation patterns were observed. Thus, we conclude that the isotopic *N. betuloides* record represents one of the most valuable tree-ring proxies for climate reconstructions in southernmost South America over the past centuries.

A chironomid inferred temperature reconstruction of the last glacial-interglacial transition for Fuego-Patagonia, southern South America.

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We present a record of climatic and environmental change for the southern hemisphere region of Patagonia in the vicinity of the Cordillera Darwin Icefield (~53°51'S) for the last glacial-interglacial transition. The palaeoclimatic history of southern South America is dominated by the strength and latitudinal position of the Southern Westerly storm tracks and the sub-Antarctic front. Patagonia lies along this zone of high precipitation and past migrations of these storm tracks can be tracked through fluctuations of the Patagonian ice fields and the response of the surrounding vegetation cover. Our current understanding of late Quaternary southern hemisphere ocean-atmosphere change is largely derived from reconstruction of glacier fluctuations during the Last Glacial / Interglacial transition (LGIT), but this provides an episodic view of the changing environment that may simply reflect the changing precipitation signal. In the northern hemisphere, the Greenland oxygen-isotope record shows that the LGIT was characterised by rapid high-magnitude climatic changes. However, the duration and magnitude of southern hemisphere climatic events, such as the Antarctic Cold Reversal (ACR), and their significance in driving Fuego-Patagonian glacial and vegetation change is unclear from pollen records obtained to-date. In this study, we present a sub-centennial record of chironomid inferred temperature change from a closed basin from Punta Yartou, western Tierra del Fuego. The climate record is further supported by sediment geochemistry, pollen analysis, and lithostratigraphic analyses, constrained by radiocarbon dating and tephrochronology. There is an apparent lag between climate change and the vegetation response, but we are unable to separate precipitation, and temperature from the pollen records alone. Here, we argue that the inferred chironomid temperature record is more sensitive to changes in regional climate, helping to circumscribe the timing and extent of temperature changes that drove the fluctuations of the Cordillera Darwin ice cap during the LGIT, and disentangle the role of shifts in the focus of the Southern Hemisphere westerly winds during the LGIT at a sub-centennial scale.

Unravelling the Holocene history of the Southern Westerlies: combined terrestrial (peat) and marine records from the South Indian Ocean

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The Southern Hemisphere (SH) plays a crucial, yet understudied, role in global climate. SH mid- to high latitude climate is dominated by the rain-bearing Southern Hemisphere Westerly winds (SHW). Changes in the intensity and position of the SHW and their impact on the oceanic Antarctic Circumpolar Current, affect both upwelling and uptake of CO_2 in the Southern Ocean (SO), an area on the planet where the deep ocean is well-connected to the atmosphere and where about 40% of the global oceanic uptake of anthropogenic CO_2 takes place. Furthermore, a poleward shift of the SHW during a number of successive austral winters recently caused severe drinking water shortages in Cape Town (South Africa), highlighting the societal impact of such changes. Understanding natural SHW variability is essential for further testing climate models, as these are not yet able to accurately simulate the position and strength of the modern SHW, hampering comprehensive future projections of SO behaviour. Here we present the results of a Holocene peat core from Kerguelen Islands (49°S) investigated using a multi-proxy approach: e.g. pollen analysis, geochemistry (XRF core-scanning) and biogenic silica content (reflecting diatom abundance). Accumulation rates are very low (~0.1 mm/yr) between 9 and 5.5 kyr BP (thousand years Before Present). From around 5.5 kyr BP and onwards, a change to more humid conditions caused renewed peat formation with relatively higher accumulation rates probably caused by increased SHW influence on Kerguelen Islands. We compare our long-term terrestrial data with marine SST records from down-wind core sites. Superimposed on this long-term trend, multi-centennial variability was found from about 4 kyr BP and onwards, showing periods of both (i) higher wind intensity (increased *Azorella selago* pollen and Ti content and (ii) increased humidity (increased *Botryococcus* sp. and BSi percentages) suggesting cyclic SHW intensity changes.

Paleoenvironmental and paleoclimate changes in the subtropical Andes for the last 15ka inferred from multiproxy records

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Subtropical regions are characterized by being relatively arid environments compared to other zones, such as tropical or temperate zones, so the availability of lakes to take proper sedimentary records where to perform paleoclimate analysis is comparatively scarce. The subtropical Andes (30°-36°S) are not an exception and moreover, it is a highly sensitive region to current and past climate changes since it is located on the northern edge of the Southern Westerly Winds Belt. In order to establish the past environmental changes in the subtropical Andes since the Late Pleistocene, the multiproxy record of Laguna del Viento (LdV; 33°08'S; 70°25'W, 3160 masl), a high Andean lake located in Chile, was analyzed. The sedimentary, reflectance (VIS-RS), pollen, macro-charcoal particles, diatoms and chironomids records were jointly analyzed. The chronology of the LdV record based on 10 ^{14}C dates and a ^{210}Pb ages series for the top most part revealed that the LdV record encompasses the last ~15,800 cal yr BP. The pollen record shows the dominance of Poaceae and Ephedra along with Asteraceae and Geraniaceae during the end of Pleistocene. Between 12-10,5ka Poaceae increases suggesting more humid conditions and a temperature increase. Between 10,5-7ka the increase of *Arenaria* and Chenopodiaceae suggest the occurrence of the driest conditions for the whole record. Then gradual increase of Poaceae suggest an amelioration of dry conditions with wetter conditions peaking between 3-0,7ka. The macro-charcoal particles record shows the first occurrence of fires at 11ka with maximum fire magnitude around 10ka and 0,7ka. The sedimentary and reflectance records suggest the occurrence of cold phases between 2,4-2,1ka, 1,5-1,1ka and during the Little Ice Age. The diatom and chironomid records reflect lake changes that matches those inferred from the pollen, sedimentary and reflectance records. Changes suggested by the multiproxy record of Laguna del Viento are consistent with other records in the Subtropical Andes as Laguna Aculeo (34°S), Laguna Chepical (33°S) and Laguna del Maule (36°S) suggesting a regional climatic pattern associated to dynamic of winter precipitations associated to the Southern Westerlies Wind Belt dynamics.

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Landscape evolution in the Mediterranean-Template forest transition of south-central Chile during the Late Holocene (37°S)

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Recent climate change and anthropogenic pressure are becoming the main factor in the degradation of ecosystems in central-southern Chile, especially in the Mediterranean-temperate transition climate zone (35°-39°S). The rapid expansion of the forestry industry has displaced the last remnants of native forests to protected areas. The climate change scenarios of the 21st century are not encouraging either due to the projected dry and warm conditions. Several negative effects on those ecosystems have been proposed including the loss of services and functions, changes in spatial distributions, and extinction of species. Past environmental reconstructions can help to gather information about the occurrence of extreme climatic events, such as extensive droughts. To reconstruct the environmental changes related to the past soil erosion, vegetation, and fire regime, we obtained two sediment records using a Uwitec (1.2 m) and Livingstone piston (2.9 m) corers in the Laguna El Pillo (LEP, 37.27°S; 72.67°W, 64 m a.sl.) in September 2022. LEP is a small lake (0.1 km^2, 8 m depth) located in the transitional ecotone between the (deciduous) temperate and the Mediterranean sclerophyll-type forests, which is highly sensitive to rainfall changes related to Southern Westerlies wind dynamics and regional temperatures. Preliminary results related to the sedimentological characterization show that organic matter content (OM) is highly variable ranging between 10 to 50%. Also, massive laminations were detected visually and by X-ray imaging, which would correspond to changes in grain size linked to intercalations between fine sands and gittja. This process can be interpreted as an indicator of erosion since the soils of the study area corresponds to fine sands that were deposited by an alluvial cone during the late Quaternary from the Andes. The ongoing work and next steps for the LEP record include the deepening of sedimentological analysis, development of chronological control (210-lead and radiocarbon dating), as well, the analysis of biological proxies (pollen, macroscopic charcoal, and chironomid remains) to determine the influence of the regional paleoclimate and ultimately, human activity on those ecosystems. Acknowledgments: FONDECYT #3220525, TAQUACH-UACH, and B. Velasquez.

Dynamics of Brazil-Malvinas Confluence in western South Atlantic

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The Brazil-Malvinas Confluence (BMC) is a highly energetic convergence of surface currents in the southwestern South Atlantic. It has been detected that the BMC shifted southwards in the last decades. The transect study of the marine cores in the region of BMC indicates that the highly eutrophic sea surface condition occurred during the Last Glacial Maximum (LGM) was linked to the weak Brazil Current and intensified Malvinas Current, which refers to the northward shift of BMC. This study suggests that the latitude shifts of BMC plays an important role in controlling the heat transfer from the tropical South Atlantic to the Southern Ocean with the exchange of water masses.

The impacts of Southern Ocean changes on the tropical Pacific climate over the last 17,000 years

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Mode waters form around the Southern Ocean and spread northwards through the ocean's interior eventually surfacing in the tropics. As such, Southern Ocean circulation changes can be transmitted to the tropical Pacific impacting key climatic processes such as El Ninyo Southern Oscillation (ENSO). Yet, because of the mid-depth nature of these waters, there is a scarcity of high-resolution records of Southern Ocean derived intermediate and mode waters. It is for this reason that the exact linkages between high to low latitude Pacific Ocean over the last 17kyrs and its role on influencing tropical Pacific climate remain elusive. Temperature reconstructions from a sediment core recovered from the coast of Papua New Guinea show warming of the thermocline waters concomitant with southward shifts of the polar front and westerly winds around the Southern Ocean during the deglacial warming events. Across the Holocene, the data reveals a modified tropical Pacific thermocline structure highlighting the impact that changes in the Southern Ocean derived waters may have had on tropical sea surface temperatures and their respective atmospheric feedbacks.

Stable isotopes in lake water and precipitation along altitudinal/ latitudinal gradient and their potential for climate reconstruction in Central and South Chile

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The use of stable isotopes has been extensive for climatic reconstructions in lake sediments mainly such as paleothermometers when the relationship with environmental conditions is well established. In South America, δ18O has been interpreted as a proxy for hydrologic balance related to westerly winds but assuming isotope oxygen signal in the lake is similar to the signal found in different organisms (e.g ostracods, diatoms, chironomids). Besides, recent studies on δ18O in lake water from different Chilean lakes compared Local Meteoric Water Line (LMWL) constructed with the few data from Global Network In Precipitation (GNIP) not finding evaporation evidence, although lakes show a notorious change in water level. The aim of this research was to identify the forcings and processes to affect isotope signal in precipitation in latitudinal and altitudinal gradients and establish the relationship with biological proxies to reconstruct temperatures y/o precipitation. We installed a rainwater collector between 34°S to 40°S and measured monthly δ18O and δD in precipitation, in addition, the same isotopes were analyzed in lake water and different water sources (groundwaters, rivers) and in-situ physicochemical parameters. The continuous air temperature was recorded with data loggers. To identify biological proxies for isotope analyses, we retrieved sediment cores. We found spatial differences in isotope signals for the rain precipitation confirming the continental effect. A good relationship was found with accumulated precipitation and a weak relationship with air temperature. LMWL constructed here showed different trends with LMWL – GNIP and the isotope signals of the lakes were located under the LMWL demonstrating the evaporation effect. The geochronology of the sediment cores permitted to cover at least the two millennials, and the main change in sedimentological analyses could response to the global climate event type- Little Ice Age, then chironomids were the only potential proxy due to the continuous record in sediment cores. Although the measurements of stable isotopes in chironomids are not easy due high quantity of material and possible vital effect, is necessary to evaluate their potential as a proxy for paleoprecipitation. This research is financed by the ANID/Fondecyt projects N°11201231, N°1201277 and CRHIAM/Fondap 15130015.

Investigation of Active Tectonics of the Mahi Basin, Western India: Use of Geomorphic Indices and Seismic Data

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Investigation of active tectonics of the Mahi Basin is based on geomorphic methods and seismic data. The geomorphic indices that have been most successful are related to erosional and depositional processes associated with fluvial systems. The hypsometric curve and hypsometric integral (HI), drainage basin asymmetry factor (AF), stream length-gradient index (SL index), mountain front sinuosity (Smf index) and the ratio of valley floor width to valley height (Vf index) are used for identifying a level of tectonic activity of the Mahi Basin and its sub-basins namely Som, Anas, Jakham, Panam, Chap, Erau and Bhadar. Furthermore, indices are applied to identify areas experiencing rapid tectonic deformation within the basin. The results of several of the indices are combined to produce tectonic activity classes, which are broad-based assessments of the 'relative degree of tectonic activity in the Mahi Basin'. The results of the geomorphic indices show that the tectonic activity is greater in the northern, north-western, central parts and near the mouth of the river. Moreover, tectonic activities are greatly associated with major faults and lineaments such as Great Boundary Fault (N-S), Udaipur-Sardarpur Lineament (SE-NW), Rakhabdev (SE-NW) and Jaisalmer-Barwani Lineament (SE-NW), Kadana-Bhadar Strike-slip Fault (SE-NW-E), Mahi-Panam-Narmada Fault (SW-NW-W), Cambay Graben fault (SE-NW), etc. The anomalous values of the indices are associated with 35 historic as well as recent earthquakes occurred within and adjacent basins from 1967 to 2021. The magnitudes of the earthquakes range between 3.84 and 5.45 MW. Thus, the investigation signifies that the basin is tectonically active and a regional evaluation of the mountains in the basin suggests that detailed studies along the western and eastern fronts of the range as well as the Kadana folded mountain ranges (Southernmost part of the Aravalli Mountain Ranges) have the best chance of yielding rate of vertical tectonic (uplift), slip rate along active Kadana-Bhadar strike-slip fault, Mahi-Panam-Narmada fault and numerous active faults along the Mahi, Som, Jakham, Erau and Bhadar Rivers.

Quaternary landscape evolution as a proxy for understanding the tectonically driven uplift history of southwestern Sicily (Italy)

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Although the late Pleistocene coastal landscape of south-western Sicily between Capo Lilibeo and Capo Bianco was shaped by a uniform climatic forcing, it shows significantly different landforms in different sectors. Its western portion hosts a roughly 100 km long, gently sloping Quaternary polycyclic surface known in the scientific literature as the Grande Terrazzo Superiore (GTS). Such peculiar landform abruptly terminates east of Sciacca, where numerous, deeply incised, V-shaped valleys separate the remnants of a 20 km long flight of late Pleistocene paleoshorelines.

The southwestern Sicily coastal sector hosts the frontal structures of the Sicilian Fold and Thrust Belt as part of the collisional African-European plate boundary in the central Mediterranean. The Plio-Quaternary frontal fold and thrust system developed primarily inland with an average WNW-ESE trend and is presently active as testified by seismological, geological and morphotectonic evidence. East of Sciacca, this system crosses the coastline and in the Sicily Channel offshore follows a NNW-SSE trend, being known as the Gela Thrust Front (GTF). Although the seismotectonic framework of the area was widely studied through oil exploration data, the geometry and location of the GTF along the coastline are still a matter of debate.

This work is based on the ongoing 1/50k geological mapping of the Foglio n. 628 (CARG Project) that includes the on/off-shore transition of the GTF. Our goal is to disentangle the contribution to the landscape evolution of the regional monocline from that of the local source of deformation, i.e. shallow individual thrust faults. To do that, we aim to decipher how marine and fluvial geomorphic markers recorded the regional tectonic signal across the GTF. We also use GNSS data and on- and off-shore seismic reflection lines to constrain the active deformation and the geometry of the deep tectonic structures.

The outcomes of this research will provide new constraints on the structural and seismotectonic framework of the area.

A new radiometric oriented, sub pixel resolution shoreline extraction method using satellite images in sandy beaches

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Shoreline variations drive the coastal landscape evolution over multiple spatial and temporal scales triggered by climate change, sea level variations and tectonic differential vertical movements. Sandy coasts are the most sensitive to coastal erosion and accretion processes, and, at the same time, these coasts frequently host valuable anthropogenic assets. For this reason, many different remotely sensed shoreline extraction techniques have been proposed in the literature, providing valuable tools for improving coastal management. Despite this broad interest, the water/sediment interface definition is still poorly investigated from a radiometric point of view. Moreover, most of the methodologies used by the scientific community are based on a pixel-bounded approach whose outcomes must follow the pixel geometry and resolution.

We identified the coastline signature from a radiometric beach profile and proposed a time-saving, sub-pixel resolution approach for the shoreline extraction capable of robust performance with freely satellite images as input data through an interpolation method. We explored the limits and strengths of our approach comparing achieved results with outcomes from one of the most used pixel-bounded methods, that adopt a thresholding approach, and a validation performed with a GNSS-detected shorelines from field surveys on three sandy beaches in Sicily (Central Mediterranean). We used satellite images with different pixel-size resolutions to demonstrate that in sandy coastlines, even with low-resolution satellite images, we reached an accuracy of up to 95% with respect to the GNSS-detected shoreline.

The proposed shoreline extraction method could represent a valuable tool for coastal management and coastal erosion risk detection and mitigation. Moreover, such a method could be used for the shoreline evolution time-series extraction, which could be treated as proxies to study the climate forcing on the coastal landscape evolution.

Evidence of tectonic activity from river terraces and alluvial fan surfaces from Kachchh: A stable cratonic region in NW India

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In the last few thousand years, the coast of the Kachchh Upland (KU) region in northwest India went from being a shallow marine gulf to being an intertidal/continental environment (1 to 4 meters above sea level) and a salty desert called the Banni plain. In this area, which is bounded to the south by the Northern Hill Range (NHR, a series of outcropping fault propagation folds), the interaction of tectonics and climate caused the sea level to slowly go down from a peak of 2-4 m (around 6000 to 2000 BP) to its stable level today. During the time when the sea level went down, a pattern of ancient rivers caused a delta area to form. This delta area was controlled by the tides until the river network disappeared around 2000–3000 years ago because of tectonic activity and a dry climate. Subsequently, sedimentation from seasonal rivers formed a conspicuous deltaic-alluvial fan alignment in front of the NHR, suggesting that the emerging Kachchh Upland's tectonic activity is one of the leading causes of such a fast Landscape Evolution (LE). Preliminary findings of the fault scarplets analysis near the Jhura dome, the highest anticline in KU, support that such activity drove the LE but the pattern and rates of such tectonic forcing remain still not understood. To provide new constraints useful for the comprhension of the tectonic forcing on the LE of this area, morphometric and geochronologic studies of the sedimentary sequences were carried out from river terraces and alluvial fans. The findings of our study aim to improve the knowledge of the uplift history of the Jhura dome and the seismotectonic framework of a region that has experienced numerous earthquakes within a 500 years.

The Quaternary uplift of the Tyrrhenian side of the Central Apennines: insights from the Middle-Upper Aniene River Valley

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The central Apennines is a Neogene NE-verging thrust-and-fold belt developed as a consequence of the convergence between Eurasia and Adria-Africa plates. The Plio-Quaternary evolution of this portion of the Apennines is characterized by the last Pliocene compressive phases, the subsequent extensional tectonics, and the regional uplift that shows an increase since the end of lower Pleistocene. Compared with the Adriatic flank, the Tyrrhenian one is displaced by extensional tectonics which, interacting with regional uplift, climate, and bedrock configuration, makes the comprehension of the landscape evolution more complex.

The Middle-Upper Aniene R. Valley is located on the Tyrrenian flank of central Apennines. Due to the presence of abundant Quaternary deposits such as terraced fluvial deposits and calcareous tufa, it represents an optimal case study to investigate the Quaternary evolution of this portion of the Apennines. However, despite the abundance of these deposits, the recent evolution of this area has been poorly studied.

In this work we investigated the hydrography (river longitudinal profiles and χ-z plot) and topography (swath profile, slope, and local relief) of the Aniene R. basin coupling these data with field observations and geochronological analysis on the calcareous tufa outcropping in several locations along the valley. Finally, a river longitudinal profile inverse model was applied to unravel the recent uplift history of the area.

The results allowed to trace the Quaternary evolution of the Middle-Upper Aniene R. Valley. In particular, the study of the geometries, extension and thickness of the deposits as well as the dating of the calcareous tufa deposits, provided a mean incision rate comparable with the uplift rates obtained from the inversion model and with the values calculated elsewhere in the central Apennines. The inversion of the Aniene longitudinal profile indicates that a capture event ruled the recent evolution of the valley.

The determination of the age of calcareous tufa deposits has also shown how, in the Aniene R. Valley, the deposition of these deposits occurred only in cold periods (MIS 3, MIS 4 and MIS 6), suggesting that this process was mainly related to river dynamics (i.e. presence of knickpoints) and tectonics rather than temperature.

Loess is like hot sauce

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Early definitions and descriptions of loess defined/described it as eolian silt. But as loess became more widely studied, and especially as it became mapped in detail across Europe, it became increasingly evident that a wide variety of fine- and medium-textured eolian sediments occur in nature. Cover sands grade into sandy loess which grades into silty loess, and all manner of “in-betweens”. No longer can we say that loess is simply eolian silt. Like hot sauce, which in the USA used to be dominated by only one brand (Tabasco Brand Pepper Sauce) but which now can be found a dozens of flavors, colrs, and degree of “hotness”, loess is now viewed as a rich and texturally diverse eolian sediment. In this talk, I bring forward a variety of detailed grain-size curves from loess deposits across Wisconsin and Michigan – states in the Great Lakes region of the United States. Much of the loess here has bimodal grain-size curves. Some of the bimodality is associated with mixing of sand into silty loess, both syndepositionally and post-depositionally. But other loess deposits have a more complicated and elusive genesis. Even among the silt-dominated loess deposits, the wide range of grain-sizes provides opportunities to evaluate paleoenvironments of deposition. Indeed, loess IS like hot sauce – it comes in all flavors.

Investigating and reconstructing complex sedimentary histories from loess – the Slivata story continued

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Loess-palaeosol sequences often provide one of the few long term, spatially extensive terrestrial archives of Quaternary environmental change. Many profiles in Central and Eastern Europe suggest almost continuous deposition responding to orbital scale drivers. However, there are growing numbers of studies that demonstrate hiatuses (either erosional or paucity of deposition) and influences of more regional and localised factors in sequence development.

Loess records along the Lower Danube have been relatively well studied, however a majority of the focus has been centred on Dobrogea and sites along the Danube up to the Olt tributary. In the upper sections of the Lower Danube, and in proximity to the Iron Gate, there are only a handful of archives that provide high-resolution records extending beyond deglaciation. At the same time the influence of competing air masses, distance from any major ice sheets, proximity to the Carpathian Mountains, and potential discontinuous permafrost influence resulted in a very dynamic and highly complex sedimentary sequence.

Here we build on our recent work that aimed to reconcile signals preserved at two loess-palaeosol profiles at Slivata (Fenn et al 2021). The top six meters of the Slivata 2 profile were sampled at a 2 cm resolution for sedimentary proxies and eight new luminescence samples collected. We present 16 new OSL (4-11 µm quartz) ages that extend the chronologies for both sites and provide a higher resolution record of environmental change over the last 50 ka in North Bulgaria. Additionally, the results of grain size, grain shape, grain sphericity, magnetic susceptibility, and colour analysis are presented for the Slivata 2 profile. The addition of geochemical analysis at 4cm resolution aims to support other proxies in disentangling regional influences on the development of the Slivata 2 loess-palaeosol profile from global ones.

Mid-Brunhes Climate Transition and millennial-timescale climate change preserved in a 800 kyrs loess-paleosol sequence from the Suhia Kladenetz quarry (Pleven, Bulgaria): a multidisciplinary study

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Eastern European loess-paleosol sequences (LPS) are excellent archives of past climate change. Millennial-timescale climate change is evidenced in loess of the last and penultimate glacial periods. In older glacial loess, observations of climate change on millennial timescales are very scarce because of various factors related to study design and geological considerations (scarcity of deposits, sedimentation rate, alterations).
The Suhia Kladenetz (SK) 27 m long profile was sampled continuously at a 2 cm resolution for bulk sediment. Magnetic and colorimetric measurements were performed on all 1336 samples. Mid-infrared spectrometry (ATR-FTIR; 719 samples) and granulometric measurements (249 samples) were acquired continuously at a lower depth resolution. Altogether, the multidisciplinary data reveal millennial-timescale climate change in the last and penultimate glacials (MIS 4-2, MIS 6), as previously reported. In addition, the data provide the first evidence, in an Eastern European LPS, of millennial-timescale climate change preserved in an earlier glacial period (MIS 12) from short term cyclicity observed in various proxies stemming from magnetic, colorimetric and ATR-FTIR data. We evaluate the observed short-term cyclicity against well-established marine paleoclimate archives (e.g. Ionian sea KC01B planktic foraminifera composition, EPICA δD records) as well as speleothems (e.g. Sofular Cave δ^{13}C paleo-precipitation record).
Combining observations from mineral magnetic and ATR-FTIR analyses, we reliably characterize the occurrence of tephra material. The SK LPS has one outcropping tephra. Further, the data suggest the presence of several crypto-tephra layers of which five are observed in other LPSs from the region at similar stratigraphic positions. The stratigraphic positions of the other crypto-tephras undetected in the regional terrestrial archives so far, appear to agree with macroscopic tephra layers preserved in the Lake Ohrid sedimentary record. The observation of millennial-timescale paleoclimate cyclicity in LPS multidisciplinary proxy data and the identification of cryptotephras within the same record provides a unique opportunity to tune the stratigraphic position of the crypto-tephras to ages of reliably dated (^{39}Ar/^{40}Ar) tephrochronological records; thus increasing the importance of terrestrial paleoclimate archives.
Finally, insights into long-term (post-and pre- Mid Brunhes Transition) climate change are sharpened from the multidisciplinary data and evidence the impact of competing Mediterranean versus prevailing continental climate regimes.

Inconsistent variations of biomarkers in loess-paleosol sequences across Eurasia

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We present results of a comparative study of biomarkers on loess-paleosol sequences in different climatic regions within the Eurasian loess belt. The original aim of this study was to obtain information of biogenic remains for paleoenvironmental reconstruction in these regions. The chosen sites include southeastern Poland with distinct periglacial features, southern Russia to the northeast of the Azov Sea with possible fluvial input, southern Tajikistan in the highland of Central Asia and Xinjiang in northwestern China under the influence of the mid-latitude westerly circulation, as well as those from southern, central and western Chinese Loess Plateau. The measured biomarkers include mainly *n*-alkanes, *n*-alkanols, *n*-fatty acids and fatty acid amides. The most surprising observation of the study is the lack of systematic differentiation between loess and paleosol for samples from Poland, Russia and Tajikistan. This is in contrast to the clear relationship between biomarkers and lithology for the loess and paleosol stratigraphic units documented previously and here in samples from Chinese Loess Plateau. The distribution patterns of *n*-alkanes in loess and paleosol samples from Europe and central Asia are characterized by the dominance of low carbon number, again different from those with high carbon number for the samples of Chinese Loess Plateau. Several factors may cause the discrepancies described above, which include the source of biological materials, e.g. types of plants, climatic conditions, sedimentary and post-depositional environments, as well as microbial activities. We examined fatty acid amides, the nitrogen-containing biomarkers, in the samples and revealed their different distribution patterns among the studied sections. An attempt was made to develop new indexes of fatty acid amides for reconstructing regional paleoenvironments using biomarkers in the European loess. However, interpretation of the experimental results is far from straightforward and requires further investigation. This study highlights the complications in the biomarker signals from the loess and paleosol sequences in Eurasia and calls for caution in the use of climate proxies for paleoenvironmental reconstructions.

Impact of analytical approaches on geochemical composition: Implication for palaeoenvironmental studies of loess

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The features of environment in which loess had been formed can be reconstructed on the basis of a variety of proxies. In particularly research focused on geochemical approaches has increased exponentially in the recent years in loess literature. However, there are several methodological approaches available for obtaining elemental composition of samples and to date these approaches have not been cross-verified in context of the palaeoenvironmental interpretation of the results. Therefore any studies using published datasets assume the results from various methods are comparable.

To test for the results and their impact on environmental interpretation 10 loess samples from different locations were analysed using the three research methods; two Inductively Coupled Plasma (ICP) analysis with different preparation method and XRF. To dissolve samples for ICP analysis one preparation involved among others HF as the main acid treatment, and second used fusion of bulk sample by high temperature in the presence of flux (lithium borate), and subsequent dissolution of the consolidated alloy in the nitric acid. Additionally for all approaches grain size influence on final chemical makeup was also tested with samples analysed as bulk and <63 μm fraction.

The research shows both ICP approaches provide comparable results in the scope of major elements (especially the mobile ones), except e.g. TiO_2. The XRF results are typically offset which can in particular affect CIA (Chemical Index of Alteration) calculations. Further differences can be observed for trace elements which is linked to the only partial digestion of some more resistant mineral phases by “HF-based digestion”, in comparison to the “lithium borate fusion”. These results demonstrate that different ICP preparation methods are strongly not comparable when investigating trace and REE elements as the would lead to different paleoenvironmental and provenance interpretations. Finally, removal of coarser material only increases the share of some elements (especially REE) without affecting the trend of UCC-normalized plots.

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Fault displacement hazard from distributed faulting during normal and reverse earthquakes

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During surface faulting earthquakes, displacement on secondary faults or factures may occur off the trace of the principal fault (PF), in the vicinity of the PF or up to many kilometres away. They are called distributed ruptures (DR). Though DRs are discontinuous in nature and characterized by lesser amount of displacement compared to the PF, their occurrence may threaten structures the safety and functionality of which are sensible to low levels of permanent ground displacement, such as critical infrastructure. Often DRs occur in unpredictable locations, without previous geologic evidence, making the assessment of fault displacement hazard from DR challenging. In this work we explore the characteristic of DRs from the analysis of numerous historical reverse and normal surface ruptures contained in a new release of the 'SUrface Ruptures due to Earthquake (SURE)' database (SURE 2.0, Nurminen et al., 2022). The database contains slip measurements and mapped traces of 50 historical surface ruptures of global, dip-slip and strike-slip earthquakes occurred between 1872 and 2019. The novelty of the SURE 2.0 database compared to the previous version is a ranking scheme which categorize the ruptures on the basis of geological information. In this work we analyse the distance-frequency and displacement distributions of reverse and normal events using the ranking information. The results have implications for deriving regressions that can be used in probabilistic analysis of fault displacement hazard.

A first comparison of instrumental European Grand Motion Service by Copernicus data with short and long term geological vertical movements for the Italian coasts

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Space geodetic data from the Sentinel-5 satellite released by the Copernicus European Ground Motion Service have been analyzed in the 2016-2020-time range. In the digital platform (https://egms.land.copernicus.eu/), the preponderance of the data suggests that the Mediterranean region is stable to slightly subsides, while Fennoscandia and Iceland appear to uplift (up to 7-10 cm/yr) possibly as result of long-term glacial isostatic rebound. To test the geological significance of the coastal smaller-scale variations in the Mediterranean region, we take Italy as example for constraining the subsidence components. To do that, we have compared the vertical component of the Sentinel data with movements calculated from the long- (MIS 5.5, 119 ka BP), and short-term Holocene (last 5 ka) geological record, and GPS instrumental movements. We have also chosen MIS 5.5 and Holocene on some coastal areas. Geological, GPS and Sentinel data have been found to be coherent in uplifting volcanoes such as Etna and Campi Flegrei. In the latter, a significant uplift (averaging 8 cm/yr) occurs at Pozzuoli. At Ustica volcano subsidence is consistent with GPS data but mismatch with slight uplifts indicated by both MIS 5.5 and Holocene evidence Sentinel data are consistent with geological and GPS data even in "virtually stable" areas of Sardinia, where a 119-ka fossil tidal notch is found at altitudes between 4 and 8 meters. Elsewhere, Sentinel data appear to indicate also fault-related differential subsidence (up to 2 mm/yr) such as in between the Piana Pontina and the Volsci Range. At Venice, the geological and tide gauge data indicate subsidence in agreement with Sentinel data. Generally, long and short-term subsidence in the Po, Pontina and Volturno coastal plains are also in line with Sentinel data due to the local interaction between sediment compaction and regional to local long term tectonics. In more active tectonic areas with both long and short-term uplift, such as southern Calabria and eastern Sicily, where both Sentinel and GPS data indicate a slight subsidence, inconsistency has been observed at a local scale, where more transtensive and transpressive faulting may more effectively contribute with very short-term vertical deformation.

Building the paleo-seismic history of Allah-Bund fault, Great Rann of Kachchh, Western India

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During the early Jurassic, the peri-cratonic Kachchh basin formed. After the Himalayan collision (40 Ma), the Mesozoic active rifting of this basin that occurred between 245 and 66 Ma was interrupted, which caused the stress to switch from extension to compression. Western India's Kachchh, which is regarded as a Stable Continental Region (SCR), has recently seen multiple earthquakes of a considerable magnitude, including those in 1668 CE (Mw 7.0), 1819 CE (Mw 7.8), 1845 CE (Mw 6.3), 1956 CE (Mw 6.0), and 2001 CE (Mw 7.7). Since the 17th century, the Kachchh region has hosted at least four destructive moderate to large magnitude of earthquakes. Except for the Allah Bund earthquake in 1819, none of these earthquakes had a surface rupture. Despite being the second-largest earthquake in the stable continental region (SCR), this event has not been examined from the perspective of current knowledge of earthquake seismology. A 90 km long scarp was created by the 1819 Allah Bund earthquake, limiting the flow of rivers that had previously flowed through the Great Rann of Kachchh (GRK) region and discharged into the Arabian Sea. The tectonic forcings present in the area and the paleo-seismic signatures will be the main focus of this investigation. A detailed tectono-geomorphic map was prepared using the remote sensing dataset, and the geomorphic markers were identified. We have excavated the Nara River section where the primary deformation due to the earthquake events can be seen and collected 8 OSL samples from the section. Before this study, the primary deformation had not been reported yet due to this event. This study will suggest whether the Allah-Bund scarp has resulted from a single 1819 event or multiple past seismic events.

First evidences of tilted MIS 5.5 tidal notches: new insight for the Late Quaternary tectonic evolution at Capo Rama (NW Sicily, Italy)

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In the frame of the "Geoswim Programme developed and described in many recent papers, a geomorphological survey along a stretch of the Gulf of Castellammare eastern coast, south of the "Riserva Naturale Capo Rama" (NW Sicily, Italy), has been recently accomplished.

The survey was carried out by combining snorkeling swim technique, which provided rough measures of lateral variations in geomorphological and geological features and ecological and hydrological parameters, with classic field geologic-geomorphological survey. The investigated area consists of a rocky cliff, about 7 km long and up to 30 m high, which displays a fairly straight NNW-SSE trend. It is shaped in a Meso-Cenozoic shallow water carbonates with a limited outcrop of Tertiary clays. At the top of the cliff there is a wide marine terrace across which stepped landforms, such as a widely extended small terraces, can be recognize.

During the swim survey we observed the present-day tidal notch which shows typical morphometric parameters: it is well carved on both fine limestones and coarse carbonate breccias and it displays a depth up to 4 m long at fresh water springs.. The depth at the toe of plunging cliff ranges from 15 to 40 m. Moreover, we observed some fossil tidal notches, which are carved only on high resistant limestones„ such as sea-caves or sites covered by breccias deposits, at elevation ranging from 1.9 to 15 m a.s.l. moving southwards. The inner margin detected across the marine terrace has an elevation ranging from 52 to 80 m a.s.l. moving in the same direction.

We assume a MIS 5.5 age for the fossil tidal notch, based on radiometric U/Th and OSL analysis of fossil shells on coastal deposits outcropping about 1 km far from the southernmost fossil tidal notch detected. Furthermore, a Middle-Late Pleistocene age can be attributed to the inner margin, by applying the same tilting rate calculated for the fossil tidal notch.

In this work we illustrate first evidences of paleo sea-level indicators, detected along this 10 km long surveyed coastal area, that could be useful for better understand the Late Quaternary tectonic evolution of this coastal sector.

Late Pleistocene caves and their importance in the Mexican paleoenvironmental reconstruction with microvertebrates.

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Mexican Pleistocene paleoenvironmental (including paleoclimate) quantitative reconstruction with vertebrates are very recent. The first and most ecometrics used in Mexican vertebrates are stable isotopes on megafaunal remains; however, the paleoenvironmental reconstruction are usual very similar: some mammals present grazer diets, others browser, diets and still others are mixed feeder, inferring a grassland with open forests. The question is what kind of forests were those open forest and what was the paleoclimate? To answer this question, microvertebrates animals such as amphibians, reptiles, and small mammals are excellent proxies to reconstruct de environments in the past, and the caves are an excellent place for their preservation. In Mexico there have been more than 20 caves excavations, but very few had a controlled stratigraphy, dates, and small vertebrate studies. We present the inferred paleoenvironmental and paleoclimatic information from Loltún Cave, San Josecito Cave, and Huautla Caves System, in Southern, Northern, and Central Mexico, respectively. We use the Ecogeographical Mutual Range, the Habitat Weighting, and Ecological Niche Models methods to infer the paleoclimate of the different caves using the climatic niche and biogeography data from the nearest living relative of identified fossil taxa. Loltún Cave has an assemblage of amphibians and reptiles that infers a cooler and wetter paleoclimate between 40 000 – 30 000 years BP. In San Josecito Cave the assemblage of reptiles, small mammals and birds infers a warmer and drier paleoclimate for 34 892 ± 4077 years BP. For Huautla Caves System the presence of amphibians, reptiles and bats infer a paleoclimate similar to today during the 12,431–12,692 years BP. The paleoclimatic inferences for the three caves are consistent with other proxies such as pollen, diatoms, and speleothems in near paleontological sites. We emphasize the importance of the caves, the microvertebrates studies and the use of new methods for paleoenvironmental reconstruction to better understand the climate of the past and their effect in the biogeographic changes of the organisms.

Geomorphological evidence of active tectonics in northwestern Albania

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Albania is a very seismic country as confirmed by historical and recent earthquakes, including the Mw 6.4 November 26, 2019. This earthquake hit northwest Albania, opening the question on the level of seismic hazard in this region of important industrial, commercial and touristic growth, where major cities (Tirana, Kruja and Durrës) lie, with their historical centres and the densely populated extensive areas of new urban sprawl.
Starting from the survey of the effects induced by the 2019 earthquake, we carried out the analysis of the main tectonic features in the epicentral and surrounding areas, through field observations and remote sensing investigations, integrated with the analysis of historical and instrumental seismicity. The study is addressed to identify the active faults and folds able to produce deformation and/or rupturing at or near the surface in NW Albania.
Seismic data confirm the compressional regime acting in this region and morphotectonic evidence clearly show that the growing of the fault and fold systems influences the local morphology and the drainage pattern. Very steep and rectilinear fault scarps are associated with the major NW-SE striking thrusts and back-thrusts running with lengths reaching 50 km along the Kruja mountain front and the edges of the Durrës and Vora Hills. Fluvial diversions and wind gaps are clear evidence of the ongoing compressional regime and the associated thrusting and folding processes that control the landscape evolution between the Kruja thrust front and the coastline. At the same time, the activity of the major deep-seated geological structures, highlighted by geophysical investigations, induces the passive movement of the skin-deep structures and, controlling the regional uplift rate, it influences at large scale the landscape morphology. All the collected data suggest that the November, 2019 seismic event is not representative of the maximum seismic and surface faulting hazard in NW Albania. More detailed studies on active tectonics and palaeoseismological investigation are in process to better characterize the seismogenic sources and to define the precise location of the capable structures and the associated surface faulting potential, in the perspective to mitigate the risks due to the maximum expected earthquake in this region.

High-latitude Northern Hemisphere forcing of the Intertropical Convergence Zone in the tropical Atlantic - South American sector

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A major paradigm in paleoclimatology holds that shifts in the mean position of the Intertropical Convergence Zone were the dominant climatic mechanism controlling rainfall in the tropics during the last glacial period. Here we present a new paleo-rainfall reconstruction based on a high-resolution speleothem d 18 O record from north eastern Colombia, which spans most of the last glacial cycle. Our results suggest that the strength and positioning of the ITCZ over northern South America was more strongly affected by summer insolation at high northern latitudes than by local insolation during the last glacial cycle. Colder temperatures and ice sheet growth in the Northern Hemisphere (NH) displaced the ITCZ southward, increasing rainfall over Colombia, and resulting in an antiphased relationship with the Cariaco basin record in response to orbital forcing. This new record provides a better understanding of the forcings associated with ITCZ rainfall, which are in part different from those that control the South American Summer Monsoon (SASM). High-latitude Northern Hemisphere summer insolation was the dominant factor modulating the positioning of the ITCZ in the Atlantic-South America sector during millennial-scale events, such as Greenland Interstadials, Greenland Stadials and Heinrich Stadials.

Assessing neotectonic deformation through high resolution DEM Analysis. La Rinconada Fault, Eastern Precordillera. Argentina.

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The Andean orogenic front in Central Western Argentina (31º–32º S), is located at the foothills of Precordillera, and evidenced by Quaternary-active contractional structures, concentration of instrumental seismicity and destructive historical earthquakes. Quaternary alluvium deformed by faulting and folding along the La Rinconada fault provides excellent examples of active tectonic and climatic interplay, which is poorly understood. Our work aims to critically analyze the sensitivity of specific morphometric parameters obtained through DEM analysis to identify or suspect quaternary deformation, where the geomorphic imprint of neotectonic deformation is subtle or absent. Drainage network gradient and normalized steepness index (Ksn) were calculated to identify sectors where the erosion or uplift rates are more important. Longitudinal river profiles and knickpoints were also used to evaluate the equilibrium state of the drainage. Detailed mapping alluvial terraces was the cartographic base to understand how the Quaternary deformation is distributed.

We found evidence of drainage disequilibrium shown by several scattered knickpoints associated with high Ksn values. Concentration of these knickpoints are related to the hanging wall of the La Rinconada fault, mainly in areas where Paleozoic limestones crop-out. In outcrops of softer Neogene rocks a smaller number of knickpoints were determined, which could be linked to different factors. These heterogeneities evidence that careful field controls are necessary to link these parameters to subtle features of Quaternary deformation. However, detailed topographic analyses are promising to recognize meaningful trends in heights and gradients in different terrace levels, to quantify the geometry of faults and folds at the sub metric level. The development and improvement of these techniques will allow a better quantification of Quaternary deformation and to improve subsurface modeling for Seismic Hazard Assessment.

The earthquake ground effects accompanying the November 12, 2017, Sarpol-e-Zahab earthquake and ESI 2007 intensity, and extract locations with evidence of Quaternary paleo-earthquakes

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Sarpol-e-Zahab earthquake, November 12, 2017, Mw 7.3, occurred in Iran near the Iran-Iraq border, is the largest instrumental and historical seismic event recorded around this region. It was felt over an area of more than 800,000 km^2 with no reports of the surface faulting. The affected fault zone of this strong seismic event is located between the Mountain Front Fault and High Zagros Fault of main Zagros structures both striking NW-SE, closer to each other in northern west part of the region. Heavy building damage and numerous related environmental effects were caused by this earthquake. We assessed the macroseimic intensity of this earthquake using its available descriptions of the environmental effects and the building damage. According to the largest earthquakes reported around this region (such the ones occurred in 958AD and 1150AD both with reported magnitude 6.4), more investigation is needed to find more relevant information of the region seismicity, paleoearthquakes and seismic hazard. In this study, using the remote sensing and the satellite images, we start to analyze this region by concentrating on the environmental effects to find the last earthquake evidence. These effects can consist of rock-falls, liquefactions, ground features, and others, especially the triggered landslides; then, the intensity values can be assessed based on ESI07 macroseismic intensity scale. Therefore, in this study, we also try to find the suitable locations for sampling and dating the earthquake evidence to identify the region Quaternary paleo-earthquakes.

Poster - sessions 5, 48, 63, 68, 105, 155, 179, 181, 185, 204

Environmental DNA in the tsunami deposits of the 2018 Palu-Donggala event

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Landslide-triggered tsunamis, although relatively rare, can have catastrophic effects on coastal communities. Their geological and hydrodynamic characteristics remain difficult to constrain due to limited number of studied examples. The palaeotsunami records of these events are rare and the mechanism which caused the tsunami is often unambiguously assigned. Here, we analyzed environmental DNA extracted from sediment samples emplaced on three sites in Palu Bay, Sulawesi, Indonesia, by the 2018 Palu-Donggala tsunami, which is known to be caused by landslides after the earthquake. This work applies a novel approach to understanding microbial impact of landslide-triggered tsunamis on coastal environments. Environmental DNA analysis is a promising approach to enhance the current multi-proxy framework when other evidence is variable.
Our results show that the environmental DNA in the tsunami-deposited sand differs significantly from the underlying non-tsunami-derived sediments and soil. A multivariate analysis shows that microbial communities in the tsunami deposits of all three sites are significantly different from those in the pre-tsunami layers (p-value = 0.0003). Notably, the difference in environmental DNA was still present at a site with limited grain size evidence between the tsunami and non-tsunami sediments. The study of the Palu-Donggala event shows that this microbial community difference between tsunami deposits and the underlying sediments and soil is impacted by tsunami disturbance, and this change in microbial communities detected using molecular techniques can be utilized to improve the reconstruction of geohazards in coastal environments.

Previously undocumented early-Holocene activity of Mount Edgecumbe, Sitka region, Alaska

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The Mount Edgecumbe Volcanic Field (MEVF) is located on Kruzof Island, 16 km west of the town of Sitka, Alaska, USA. In April 2022, the previously dormant MEVF showed renewed seismic activity, and retrospective study revealed steady inflation has been occurring at the volcano since August 2018. Previous to this unrest, local mapping and documentation of tephras in marine cores have shown a major burst of activity of the MEVF in the late Pleistocene, likely related to deglaciation of the region. These eruptions deposited several metres of tephra in and around Sitka, and 15-20 cm in the Juneau region about 160 km to the NE. However, there is little understanding of the eruptive activity during the Holocene, with only two reported tephras and a pyroclastic flow identified on Kruzof Island. Our initial research and oral history of the indigenous Tlingit people suggest that it has been more active than previously thought.

We mapped a previously undescribed tephra sequence that contains 5-7 individual depositional units on Biorka Island, 17 km to the south of the volcanic field. Initial radiocarbon dates from below the sequence (9820-10180 cal yr BP) and mid-sequence (8200-8380 cal yr BP) suggest that these tephras were deposited during the early and middle Holocene. We successfully obtained glass geochemistry from seven of eight samples, with results geochemically consistent with MEVF tephras found in marine cores across Sitka Sound. To further clarify this potential Holocene sequence, we returned to the tephra sequence on Biorka Island in summer 2022. We collected new samples to expand the geochemical and radiocarbon dataset, mapped other exposures, and extracted new peat cores from Biorka Island and elsewhere around Sitka. These findings will aid the pressing need to better map, establish the eruptive history, and adjust hazard assessments of the newly-active Mount Edgecumbe.

Interplay of anthropogenic landscape shaping and fluvial dynamics

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Land rehabilitation is a strategy for restoring near-natural landscape systems in anthropogenically influenced environments. Especially in post-mining landscapes after open-pit mining, land rehabilitation gives opportunities and potential for near-natural landscape modeling. To evaluate its success, biological monitoring approaches with a focus on biodiversity are common. However, the loss of natural soils, which are the result of long-term formation, is an irreversible damage to the pedosphere. The natural soil functions must be completely re-established and it is difficult to examine its success.
Our study area is located in the Inde River catchment (North Rhine-Westphalia, Western Germany), which is part of the international River Basin District Meuse. Due to the progress of the open-pit lignite mining, a 5 km long river course had to be relocated. To create a near-natural landscape and an appropriate development corridor for the river, a 12 km long river relocation was designed. The artificial river section “Neue Inde” is still geomorphologically “naive” and characterized by temporary, highly energetic morphodynamic processes resulting in strong erosion processes in the river bed and the surrounding area. Our study investigated initial soil formation in a morphodynamically active artificial river valley, constructed with a restoration substrate called “Forstkies”.
To characterize morphodynamics and to detect initial soil formation processes, we analyzed a transect of seven soil profiles. It includes floodplains and slope areas further away from the river. Allochthonous flood sediments can be differentiated from the underlying artificial restoration substrate by inherited enrichment of the heavy metals Pb, Zn, and Cu. First initial post-sedimentary alterations are detected employing common soil parameters (grain size, $CaCO_3$, total organic carbon and pH value) and geochemical weathering indices. The quality of the soils is appropriate to the state of development. The results obtained can be helpful for the planning of future restoration in post-mining landscapes.

Development of Holocene terraces along the Tsailiao River in the Western Foothills, southwest Taiwan

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Topographical and geological researches into fluvial terraces can reconstruct paleoenvironmental and sea-level changes caused by climate changes and crustal deformation. The island of Taiwan has been formed by the collision between the Philippine Sea plate and the Chinese continental margin of the Eurasian plate. The Western Foothills between the Central Range on the east and the Coastal Plain on the west defines the frontal zone of this collisional belt. Fluvial terraces are well developed along the Tsailiao River which flows through the Western Foothills. The surfaces of the terraces have been uplifting and deforming due to the activity of the zone. However, the developmental process of the terraces has not been clarified because previous researches are insufficient for accurate distribution and of the terraces, as well as lithological and chronological descriptions of their deposits. In this study, we have investigated the detailed distribution of the terraces, and discuss the forming process, chronology, climatic backgrounds, and tectonics on the terraces on the basis of the analysis using DEM, field works and radiocarbon dating. As a result, the terraces have been divided into three categories by the heights from the present-day riverbed and by the degree of dissection of the terrace surfaces. All the deposits of the terraces are composed of channel infill and overlying flood-plain deposits. These three terraces were formed in the early (Younger Dryas), middle and late Holocene for the higher, middle, and lower terraces, respectively, by climate warming and crustal uplifting. The terrace deposits have yielded marine invertebrate and land mammal fossils, but they had been derived from underlying sediments of Early and Middle Pleistocene in age.

Anthropogenically driven sinuosity variations on the channel of the lower Rio Grande, Texas, USA

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Large-scale dam building and river diversions on the Rio Grande over the last one hundred years, have reduced its discharge to 18% of pre-dam-building values, and have nearly eliminated the suspended sediment load. Present day suspended sediment concentration delivery to the Gulf of Mexico is 1% of pre-dam-building values. These new anthropogenic conditions have forced the river to adopt morphological changes. Here we explore how the river has adjusted the sinuosity of its channel on the delta, where the river gradient is 8 $cmkm^{-1}$ and the valley length is 88 km. We compare pre-dam sinuosity using the 1:10,000 scale International Boundary & Water Commission map of 1912, with that of 2014, using satellite imagery from the US Department of Agriculture, National Agriculture Imagery Program, with 1-meter pixel resolution. ArcGIS software was used to geo-reference the 1912 map, and to precisely measure channel length on both data sets. Our findings show that in response to the new conditions the river reduced its channel length by 10 km, from 202.35 to 192.31 km, which resulted in a sinuosity reduction from 2.3 to 2.2. This seemingly small change is the river's way to adjust its gradient to more efficiently discharge its load to the Gulf of Mexico. The sinuosity change occurred through lateral migration of the meandering channel. Worth noting is the observation that the position of the mouth of the river remained fixed for the 102-year period cover in this study. Two unexpected results are, 1- the international boundary shifted as the channel migrated laterally, and consequently the United States gained 4 km^2 of land, and Mexico lost the same amount, and 2- in the delta there are segments of the channel with sinuosities of 2.5, these are among the highest reported for any river channel.

Lower Meuse Holocene overbank deposition: persistent climate forcing and growing human impact

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For the Meuse River, located in the Netherlands, a dataset of 427 radiometric dates derived from its fluvial setting was compiled from existing literature. A cumulative probability density function (CPDF) was deployed to reconstruct the phasing in fluvial activity throughout the Holocene. Wavelet analysis was used to identify persistent periodicities in deposition or non-deposition (stability). It was found that particularly centennial-scale periodicities correlate to known episodes and modes of variability of the Atlantic climate system and solar activity – particularly that of the Gleissberg solar cycle. Major changes in overbank deposition closely followed North Atlantic climate anomalies and periods of rapid climate change, suggesting that the Lower Meuse's flooding regime is highly sensitive to such perturbations.

In addition, the CPDF results show a rise in the amplitude of overbank deposition in the last few millennia, which coincides with increasing human influence on land cover and an associated increase in sediment input from the hinterland. Whereas initial Neolithic farming societies seem to have had a limited direct impact, there are notable increases in overbank deposition during the middle Bronze Age (1800-1100 BC), the late Iron Age (250-12 BC) and particularly the Medieval period (AD 450-1500). Such periods are associated with enhanced pressure on arable lands due to agricultural innovations and increases in population density. The resulting fluvial responses in flood regime and overbank deposition did, reversely, affect cultural dynamics in the alluvial valley. Periods of increased fluvial activity coincide with a shift in occupation to higher grounds, while periods of relative stability are characterized by increased human activity in the low-lying floodplain areas.

Based on these results, it is argued that CPDFs can be a useful tool to understand flood regime changes, and to identify the impacts of climate and human forcings. This can be considered as important baseline information for current and future flood risk mitigation efforts, as they allow to establish the 'rhythm of the river' and its sensitivity to external punctuated and long-term perturbations.

Leipzig, city in a state of flux. Urban-fluvial symbiosis in a long-term perspective

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Leipzig, today a metropolis with 600.000 inhabitants, originated in the Middle Ages at the edge of the Pleiße and Weiße Elster floodplain. The place gave the city its name, which derives from Indo-European *Leibh-, meaning watery, slippery, loamy area. At least since the 12th century, Leipzig's inhabitants engaged in water engineering methods in order to secure water provisioning and allow for the use of water power and waterways. This led to an anthropogenic transformation of the existing waterbodies and related fluvial landscapes, which shaped the city for centuries. While the close connection between city and water tended to disappear in the 20th century, it is being rediscovered today through town planning, tourism and nature conservation. With its varied water history, Leipzig is a particularly well-suited case study for investigating the interdependencies between humans and water in the sense of a "fluvial anthroposphere". The city is characterised by a dense network of smaller water courses, a still-existing riparian forest, and a high density of archival sources, provided by both cultural and natural archives. The project takes a long-term perspective, investigating the period between 1000 and 1800, and combines historical, archaeological and geoscientific analyses. Its main objectives are (1) hydrological dynamics and city politics, (2) floods and droughts as social-natural events, (3) urban water pollution and (4) floodplain economies. The project stands for a decisive urban approach that provides the basis for drawing out the specifics of an urban-fluvial anthroposphere. Beside the conceptual idea, we will focus our presentation on the sedimentary reconstruction of Late Holocene fluvial and alluvial boundary conditions of the Weiße Elster, Pleiße and Parthe floodplains before and after passing Leipzig.

Geoarchaeological and stratigraphic investigations on the alluvial fan of the Riana Stream (Vedeggio valley, Southern Switzerland)

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The alluvial fan of the Riana stream lies at the foot of the right side of the Vedeggio valley, in Canton Ticino (Southern Switzerland). The fan is densely built today, and recent archaeological discoveries revealed the frequentation and presence of human settlements in the area as early as the Roman Epoch.

The activity and position of the Riana stream deeply affected human activity on the fan. The archaeological remains are observed between 5 and 0.5 m depth, with three different levels of anthropic occupation. The first level shows evidence of artisanal iron mining activities, with the presence of an ore reduction furnace. Following a major flood event, the site changed function, making way for a necropolis characterized by six infant and two adult graves. These graves are located around a mound built with large stone boulders and with an observed extent of 10 m. After these two occupation phases attributed to the Roman Epoch, the area was also occupied during the Middle Ages and the Modern Epoch, when several terraces and a massive wall are built, most likely for agricultural purposes.

The alluvial fan deposits crosscut the anthropic levels observed. These deposits consist mainly of sands and gravels, clast-supported (fluvial active band), and matrix-supported silty sands for calmer phases of hydro-sedimentary activity. Destruction phases with a reworking of anthropogenic structures and finer layers (paleosoils in terrace fill) were also observed. Remains of charcoals were sampled for radiocarbon dating; this together with the archaeological observations will provide a detailed chronological analysis of the alluvial sequence.

These discoveries are unique in the area and reveal new insights into the human colonization history of Southern Switzerland. In recent years, many investigations were carried out in Canton Ticino, providing a nice overview of the human settlements and their link to the evolution of the hydro-sedimentary activity of Alpine rivers during the Holocene. The present contribution allows us to study the historical river dynamics of the Vedeggio valley and discover complementary evidence on the palaeoclimatic and palaeoenvironmental conditions, as well as the impacts of these rivers on humans as a resource and/or natural risk.

The Holocene record of the Galera River in the Guadix-Baza Basin (SE-Spain)

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The Guadix-Baza Basin (GGB) that also includes the Granada UNESCO Geopark constitutes a unique archive of Quaternary landscape formation. As the largest late Neogene Inland basin of the Betic Cordillera that was captured not earlier than during the middle Quaternary, it hosts a spectacular erosion landscape formed by the incision of the Guadiana Menor River and its drainage system. However, due to ongoing erosion dynamics since the middle Pleistocene, highly resolved sediment records documenting palaeoenvironmental conditions are very rare. Here we present an outstanding fluvial sediment record of the Galera River within the Baza Basin, the eastern sub-basin of the GGB that provides detailed insights into early to middle Holocene landscape dynamics. The up to 15 meters thick sediment sequence contains several meters of palustrine tufa deposits indicating more humid conditions after 8.2 ka cal. BP. After 6 ka, sedimentary features suggest an increasing aridification. In a period following 4.5 ka that relates to utmost aridity in several regional environmental archives, the Galera River system switched towards strong incision that contradicts general concepts of fluvial reactions on climatic impacts. The fluvial sequence of the Galera River record, together with various proxy information provides interesting new insights into Holocene environmental dynamics in a highly erosive marl landscape. Nevertheless, there remain some open questions regarding the interpretation of fluvial behaviour that might be strongly affected by geological substratum, tectonic impacts and particular relief conditions.

The Baer knolls as a landscape that served to reconstruct the palaeodelta of the Volga in the Late Pleistocene

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1. *Independent Researcher*

Many geological sections in the ledge of the Lower Volga valley have been actively studied since the end of the 19th century. Results many years of field work showed that in all the studied quaternary sections along the Lower Volga valley alluvial sediments of the Khvalynian time (end of the late Pleistocene - early Holocene) are absent.

Numerous literatures, descriptions of wells, maps were used as research methods. We conduct geomophological mapping out in Arcgis using the SRTM DEM and studied many outcrops along Volga valley and in the Baer knolls – gyant underwater dunes of the Northern Caspian.

We consider the Volga River probably did not flow at the site of its present position in the Khvalynian time. In this regard, the question arises of where the Volga channel was located in the North-Western Caspian in the Khvalynian time. Thus, we propose the extreme western branch of the Volga ran along the foot of the Eastern Ergeni slopes, eroded the surface of the marine plain, as a result of which the Sarpinsko-Davanskaya hollow was formed, the eastern branches of the delta flowed into the Kha-ki saline. Which was one of the estuaries of the Northern Caspian, where the waters of one of the extreme eastern channels of the PaleoVolga stream probably flowed into.

In the Khvalynian time, the Volga channel in the lower reaches had multiple terminal distributary channels at different scales. Where were arcuate fluvial-dominated delta much larger (200-210 km wide) than the modern delta and somewhat reminiscent of the modern Lena delta in size. In the location of the modern Volga-Akhtuba floodplain there was probably a small central branch, in the west there was a Sarpinsky branch, and in the east, there was an Elton-Khaki branch. They were interconnected by an extensive system of branches, the relief of which is still preserved.

At the very end of the late Khvalynian time, the Sarpa and Khaki branches began to die off, and most of the water began to rush along the central branch, forming the modern Volga-Akhtuba valley.

Tectonics and climate events at the eastern flank of the Jordan Rift between the Late Pliocene and the Early Pleistocene

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The Zarqa Valley is a remarkable morphological feature infilled by basalt flows interbedded with artifact-bearing fluvial deposits, about 40 km east of the Jordan River. Based on a review of the stratigraphy and geomorphology it has been possible to document major phases of erosion and aggradation in the last 5 million years, possibly related to the Jordan Rift tectonics and climatic evolution of the Levant. Chronologic constraints of the Zarqa Valley infill have been provided by paleomagnetic and geochronologic analyses of basalts and sediments. After the former valley formation, the first infilling phase is documented by a ca. 150 m-thick succession of basalt flows (Lower Basalt) accumulated at 5.82-5.51 Ma and now constituting the maximum aggradation surface at 550 m above the sea level. Our study documented 3 million years of erosion until a new cycle of aggradation took place at the end of the Pliocene. We sampled the lowermost stratigraphic beds of the Dulayl Fm. (40 m thick), where we could identify a geomagnetic polarity reversal from normal (at the base) to reverse magnetization (at the top). Since the Dulayl Fm is covered by a 2.52 Ma basalt flow (Upper Basalt) this magnetic reversal is interpreted as the Gauss-Matuyama boundary at 2.58 Ma. This implies that at least 30 m of Dulayl Fm deposited in ~60 kyr, a fast sediment accumulation rate of 50 cm/ky. The data also indicates that the Late Miocene Lower Basalt (5.82□5.51 Ma), was slowly eroded during the Pliocene at a rate of 3.6 cm/ky.

We interpret the erosion phase during the Pliocene associated with the progressive lowering of the base level in the Jordan Valley. Palynological records from several boreholes drilled throughout the Jordan Valley, show that the Levant had a humid and warm temperate climate provided by colder polar air from the north at the end of the Pliocene, providing an aggradation phase around the Plio-Pleistocene boundary by the increasing precipitation. This event on one side could have triggered higher sediment discharge in the Zarqa Valley and on the other side higher accommodation space for lacustrine transgression in the endorheic Jordan Basin.

Facies architecture and aggradation rates of periglacial alluvial fans: control by autogenic processes or high-frequency climatic osciallations?

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Quaternary alluvial systems reveal a complex history of incision and aggradation responding to climatic forcing. However, the depositional architecture and geomorphology of alluvial fans that have evolved in response to similar regional environmental conditions can differ strongly, implying that autogenic processes may play an important role and lead to similar cycles of fan aggradation and incision that may be difficult to be distinguished from the effects of tectonics or climate change. Here, we present data from two different Late Pleistocene (MIS 3-2) alluvial fan systems in Germany. The selected fan systems formed under similar climatic and tectonic conditions, but differ in size, type, and drainage area allowing to estimate the role of climate and autogenic controls on flow processes, facies architecture, and fan-stacking patterns.

Luminescence dating is used to determine the timing of fan onset and aggradation rates. Fan onset occurred in response to climate change at the end of MIS 3 when temperatures decreased and periglacial climate conditions were established in northern central Europe. A related increase in sediment supply and strongly variable precipitation patterns probably promoted fan formation. The major period of fan aggradation was approximately between 33-18 ka, followed by fan inactivity, abandonment, and incision during the Lateglacial. The highest aggradation rates occurred during the early stage of fan building.

Sand-rich, sheetflood-dominated fans are related to larger, low-gradient fan catchments. Steep depositional fan slopes (5°-17°) favored supercritical flow conditions. Steep, dip-slope catchments enhanced stream gradients and promoted the transport of coarser-grained sediments. These fans have lower gradient slopes (2-6°) and are dominated by channelized flows, alternating with periods of unconfined sheetfloods. Meter-scale coarsening-upward successions, characterized by sandy sheetflood deposits at the base, overlain by multilateral or smaller single-story gravelly channel fills may be related to high-frequency climatic fluctuations or seasonal fluctuations in water and sediment supply. These coarsening-upward successions are commonly bounded by a paleo-active layer, from which ice-wedge casts penetrate downwards. The recurrent pattern of multistory, multilateral and single-story channel bodies with a lateral offset to vertical stacking pattern most probably was controlled by autogenic switch in avulsion-dominated systems.

River terrace formation in the Granada UNESCO Geopark (Spain): Timing and dynamics

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River terrace formations are widespread geomorphological features all over the world. The complex interplay of erosion and accumulation processes and their triggering environmental conditions, which control the dynamics and timing of river terrace formation is only one of numerous questions related to fluvial terraces that have not yet been adequately answered.

The Baza/Guadix Basin, which is part of the Granada UNESCO Geopark, located in northeastern Andalusia, provides ideal conditions to investigate the dynamics of river terrace formation. Starting in the Pliocene and persisting until the middle/late Pleistocene, the basin was a vast drainage-free depression that was continuously filled with sediments of all grain sizes originating from the surrounding mountains. At a so far unknown time during the middle or late Pleistocene, this endorheic basin was captured by a source river of the Rio Guadalquivir, and a new river system was established, cutting into the original basin sediments and leaving deeply incised valleys with several generations of fluvial terraces. At several locations, the river terraces are coupled with travertine and sinter formations. The terrace deposits as well as the tufa and travertine formations occurring in the basin are to be systematically documented, mapped, and dated.

The DFG-funded project presented here aims to investigate the evolution of this newly established drainage network. Based on luminescence dating of river terrace sediments and supported by U/Th-dating of tufa and travertine formations, we will establish a regional chronostratigraphic framework, which will provide information on the dynamics of the fluvial landscape evolution in the Basin ever since the capturing event. We expect our results to allow us to approximate the velocity of backward erosion and to determine typical incision rates for the local rivers.

Our poster gives an overview of the goals the project is aiming at, provides information on the methods applied, and presents some first geochronological results.

Pliocene-Quaternary landscape evolution of the Krško Basin (south-eastern Alpine foreland, Slovenia) based on sedimentological, geomorphological, and chronological data

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This study focuses on the Pliocene-Quaternary landscape evolution of the Krško Basin located in the south-eastern Alpine foreland, Slovenia. The basin covers an area of approximately 280 km^2 and is elongated in the west-southwest to east-northeast direction with its main tributaries Sava, Krka, and Sotla Rivers. The formation of the Krško Basin is related to the Krško Syncline which was formed by the north-northwest to south-southeast compression that started at the end of the Miocene and continues to the present day. The base of the syncline, consisting of Mesozoic sedimentary rocks is overlain by the Neogene marine and terrestrial succession followed by terrestrial Pliocene-Quaternary sediments. The latter were the main focus of our study which aimed to define the morphostratigraphy, composition, provenance, sedimentary environment, and time of deposition of these sediments. Facies analysis revealed that the Pliocene-Quaternary sediments were deposited in fluvial and alluvial/colluvial fan environments. The sediments are preserved in terrace staircase sequences, which are controlled by folding caused by the compressive tectonic regime. We conducted geomorphological mapping which was based on combining existing data, geomorphological analysis (analysis of topographic profiles and GIS-based shaded relief, elevation, slope-inclination, slope-aspect maps, and relative elevation model), ground truthing, clast lithological analysis and the evaluation of subsurface data. Based on geomorphological analyses and age dating with terrestrial cosmogenic nuclides, eight levels of Pliocene-Quaternary terraces were constrained. Clast lithological analysis revealed not just local but also distal provenance of the Pliocene-Quaternary sediments. Local character is deduced from the Triassic volcanic, clastic and carbonate rocks since all of the mentioned lithotypes are outcropping in the vicinity of the basin. However, metamorphic rocks from Pohorje Massif and Permian carbonate rocks are indicating distal provenance. Considering present exposures of identified rock formations, the main transport path was along the Savinja River.

A response of fluvial systems of different size on climate changes during the Last Glaciation in Polish Lowlands area

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Fluvial systems with different catchment sizes and discharge rates respond differently to climate change. It is assumed that large river systems (the size of the Vistula or the Rhine Rivers) are characterised by a high response inertia, while smaller rivers respond more quickly and to smaller-scale climate fluctuations. Therefore, 2 river systems were selected that operated during the Weichselian glaciation in the extraglacial zone to testify this assumption. The first example is the middle section of the Vistula River valley, which represents the main fluvial system of the Polish Lowlands. The second study area is the lower part of the Prosna River valley, a tributary of the Warta River. The sediments building the fluvial terraces of both valleys were studied on the basis of lithofacial analysis. Analysis of periglacial structures and textural features of the sediments was used to reconstruct climatic conditions during sediment accumulation. Optically stimulated luminescence (OSL) and the radiocarbon method were used to determine the age of the studied sediments.

The results obtained indicate that the river systems of the Prosna and Vistula Rivers responded differently. In the middle section of the Vistula River valley, two main periods of deposition were identified. They took place during the Late Vistulian and at the end of the last glaciation. On the other hand, in the Prosna River valley, 4 erosion-deposition cycles were distinguished during the Middle and Upper Vistulian. At the end of the Late Pleniglacial, there was a deep erosional incision in the Prosna River valley and a change in the river type from braided to meandering (a system of large meanders). In the Vistula River valley, on the other hand, erosional incision presumably took place just after the Last Glacial Maximum. Beginning at the end of the Late Pleniglacial, sediment aggradation in the Vistula valley was dominated by a braided river type.

It can be concluded that the Prosna fluvial system was characterised by high sensitivity to climate change, whereas the Vistula fluvial system responded only to major changes in environmental conditions.

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Alluvial fans as an indicator of Quaternary climate change

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Past research suggests that alluvial fans are, due to their direct coupling to the source area, sensitive to Quaternary environmental change and, thus, provide essential archives for paleoenvironmental conditions, notably climate, hydrology, and tectonics. Although they have been studied for many decades across the globe, there is no unifying scheme to view their variety in relation to the formative geomorphological regimes. The spatial and temporal approach in geomorphology indicates that the development of landforms is a function of size and time. While small-scale landforms are created by short-term events, mesoscale and macroscale landforms develop within a period of 10^4 to 10^5 years. A conceptual model for the formation of alluvial fans is developed, and their implication for Quaternary climate change is assessed, using a review of their global range and data from selected key dryland regions. We propose three main depositional regimes for alluvial fan development: i) Mountain alluvial fans, small in size and extent; ii) mesoscale pediments and bajada of (semi-) arid regions; and iii) mega fans mainly associated with Cenozoic mountain building.

Mountain alluvial fans are governed by cryogenic and nival processes, closely linked to climate change, tectonic processes such as earthquake-triggered landslides, and are often also modified by anthropogenic intervention. In drylands, mesoscale pediments and bajadas are one of the most common fluvial systems and landform features, where they are frequently associated with steep mountain fronts, closely related, and often modified by active tectonics. The formation of mesoscale alluvial fans occurs in different settings characterized by distinct relationships between sediment production and transport capacity. Although governed primarily by the climatic setting, bedrock geology can be the dominating factor, especially for sediment production. Alluvial fans in the drylands of the western United States, Mongolia, Chile, and Namibia illustrate the links to climate variability by glacial-interglacial cycles or expressed in late Quaternary pulses of increased humidity. Furthermore, mesoscale alluvial fans are common in glaciofluvial and periglacial settings, where streams have high bedload and transport capacity depending on a sediment supply especially due to frost weathering and discharge by snow and ice dynamics.

Complex fluvial archives of varied types: erosional and depositional evidence from the River Trent, Midland England

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Fluvial archives can take a variety of forms, both depositional and erosional, the latter invariably of a geomorphological nature (although there can have been subsequent burial); sedimentary and geomorphic evidence are optimally combined in river-terrace sequences. The record from the Trent, combines all these types of data. There is a sequence of terraces in the Middle Trent that has been researched over many years and was extended into the lower reaches by the Geological Survey late in the last century. The river has excavated gorge reaches of various lengths through resistant bedrock strata, interpretation of which is fundamental to unravelling its evolution. The latter has involved multiple diversion events associated with glaciation on three separate occasions. There are sporadic but important remnants of fossiliferous interglacial sediment that provide pinning points for deciphering the complex evolution of the system.

The story of the Trent began with the River Bytham, which drained from the West Midlands to East Anglia along an alignment several kilometres south of the valley axis of the modern Trent. That system was destroyed by the Anglian (MIS 12) glaciation, although various reaches became parts of later drainage, in some cases reversed. Anglian deglaciation saw the emergence of a Derwent-Soar system, derived from the Bytham but flowing into the North Sea through the newly (glacially) excavated Wash basin, crossing the Jurassic escarpment at Lincoln (giving rise to the Lincoln Gap). The constricted gorge-like course of the Trent between Nottingham and Newark was adopted at this time, although its excavation has required progressive downcutting throughout the subsequent Pleistocene, keeping pace with the lowering of the river recorded by its terraces. There is no sedimentary record in the lower valley older than MIS 8, but deposits of the Wragby (MIS 8) glaciation fill a subsurface feature interpreted as the MIS 12–8 palaeo-Trent valley. The Wragby glaciation coincided with the west-east course of the Trent between Derby and Nottingham becoming established. The Trent flowed to the Wash until deglaciation of the Devensian (MIS 2) ice sheet that had blocked and ponded the Ouse-Humber system (which drained the eastern Pennines further north).

Late Neogene-Quaternary Andean foreland basin evolution of the depositional system of the Salado-Juramento fluvial megafan, South America

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Strata in foreland basins record are the result of periods of deformation, climatic change, changes in thrust rates, and source rock variation, among others. In underfilled basins, the forebulge remains a topographic high as observed in the middle part of the Salado-Juramento fluvial megafan-SJFM in the modern Andean and Pampean foreland basin in South America (26°-30°S). The interaction between tectonics and sedimentation in the foreland basin, whose evolution is related to normal dipping slab subduction (>30°) and flat slab subduction transition, was analyzed by a sedimentary record from 42 deep boreholes. Constraining, the geometry of the basin from the Anta and Paraná formations, the evolution of the Late Miocene-Quaternary foreland basin was interpreted. The Bermejo DFS cross-section, situated along the long axe, showed a classical foreland profile produced from flexural loads originated by the Sub-Andean fold-thrust belt. It controls the synorogenic sedimentation mainly in the foredeep zone. In the NW-SE section of the SJFM, the major sedimentation occurs in the foredeep zone. The forebulge is interpreted as the Otumpa Hill-OH which could indicate an uplift stage due to flexural loads and faulting reactivation over the Late Cenozoic. The back-bulge zone is represented by a large plain, limited in the E by the Vera Block-VB. VB corresponds to ancient zones of basement weakness that were reactivated, generating a tectonic style of blocks with differential vertical movements. Presently, sedimentation rates do not exceed the uplift rates that occur in the mid-distal foreland basin in SJFM and generate differences with the other Chaco DFSs. A tectonostratigraphic model of the evolution of a DFS in a modern underfilled basin may be interpreted from vertical grain-size trends in the SJFM. Basal sandy or conglomeratic fining upward sequences are associated with higher sediment supply and higher accommodation spaces at the first stages. These sequences could be related to periods of higher tectonic activity in the northeastern Pampean Ranges, in addition to the climatic control. The top fine sandy–silty sequences indicate a foreland basin stage characterized by lesser accommodation space and higher sediment transport rates. Lateral grain-size variations also can be observed inside these major sequences.

Development and evolution of the Maggia river delta in Lago Maggiore since the deglaciation (Southern Swiss Alps)

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The delta of the Maggia river between Locarno and Ascona (Canton of Ticino, Southern Switzerland), with its typical fan shape prograding into the upper Lago Maggiore, is one of the most emblematic fluvio-deltaic landforms of the entire Alpine domain. This site is located at the crossroads between the wide and deep water-filled valley trough, which penetrates deeply into the Alpine chain, and the upper Southern Alpine valleys, which enable reaching and crossing the Alpine divide.

The compilation, harmonization, and contextualization of the regional chronostratigraphic framework, combined with the analysis and interpretation of unpublished radiocarbon ages, allowed for the determination of a new chronology and the diachronic paleogeographical reconstruction of the development and evolution of the Maggia river delta. In particular, the geomorphological history of upper Lago Maggiore is assessed, highlighting the timing of deglaciation after the Last Glacial Maximum, the reconstruction of the mean lacustrine level, and the progradation rates of the Maggia river delta during the Late Glacial (19.9–11.7 ka b2) and the Lower (11.7–8.24 ka b2k) and Middle (8.24–4.25 ka b2k) Holocene.

Thanks to the sedimentological and paleoenvironmental observations carried out in four archaeological sites on the Maggia river delta, a particular focus is done on the morphoclimatic and environmental evolution during the Upper Holocene (4.25–0 ka b2k), by evaluating the variation of the Lago Maggiore mean level and the hydrosedimentary activity of the watercourses that contribute to feeding the delta.

Understanding the timing of development and the environmental evolution of an Alpine delta, contribute to raising knowledge about the mountain geomorphological systems' response to the climate oscillations after the Last Glacial Maximum. This assessment is necessary to compare a system controlled only by natural factors, dominated by paraglacial and paraperiglacial erosion models, and a system where increasing human activity modifies the environment. In the Southern Swiss Alps, anthropogenic factors start playing a role since the frequentation of the valley bottoms and the main Alpine passes during the Middle Mesolithic (10.0–9.0 ka b2k). This role increased significantly since the Neolithic (7.5–5.4 ka b2k), with the first permanent settlements.

Geomorphology and stratigraphic record of the Murinascia Grande delta in Lago Ritóm since the deglaciation (Piora Valley, Southern Swiss Alps)

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The Lago Ritóm is located in the Piora Valley at 1849 m a.s.l., on the southern side of the Swiss Alps, in a natural basin carved by ice during the Last Glacial Maximum. The natural dam of Lago Ritóm consists of a rock sill, whereas the artificial dam was built in 1917 for the construction of a hydroelectric power plant.
The construction of the dam led to an increase in the water level in the basin from 1828 m a.s.l. to a maximum elevation of 1850 m a.s.l., resulting in the flooding of the delta of the Murinascia Grande, the main lateral tributary located northeast of the basin. However, since the summer season of 2020, the water level decreased below 1827 m a.s.l. due to the maintenance of the hydroelectric dam, allowing the emersion of the Murinascia Grande delta. The subsequent fluvial erosion caused the exposure of the fluvio-deltaic sequence.
Approximately ten meters of alluvial deposits with layers of silts and organic muds, sands from finer to coarser, and gravels were observed and described on the field. The organic sediments together with pieces of wood were sampled for radiocarbon dating at different levels in the stratigraphy. This approach was combined with a detailed 3D photogrammetric model of the delta obtained through a drone survey.
Based on previous studies on palynological records, the development of the vegetation in the area was attested during the Lower Holocene at around 9 ka b2k. As a result, the radiocarbon dating on the delta deposits will probably provide a chronology covering a period included between the Middle to the Upper Holocene (8.24–0 ka b2k). The dating, together with the estimation of the volumes and thicknesses of the deposits from the digital terrain model, will allow tracing the variation of the sedimentation rate on the delta in time.
The results will provide information about the timing of development and the evolution of an Alpine delta during the Holocene, providing evidence on the response of the hydrosedimentary regime to the climate oscillations and therefore on the palaeoclimatic and palaeoenvironmental conditions on a regional scale.

New ESR Ti ages of the fluvial terraces of Arlanzón River (Sierra de Atapuerca, Duero basin, Spain)

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The Sierra de Atapuerca is a limestone range located in the NE Duero basin (Burgos, Spain), where a multilevel endokarst system containing the oldest fossil remains in Europe is located. Previous geomorphological studies have correlated the three cave levels of the Atapuerca karst with terraces between T2 (+82-91 m) and T6 (+44-46 m) of the Arlanzón River according to their altimetric position. Therefore, establishing an accurate chronological framework for the fourteen-stepped terrace system of the Arlanzón river is important to better understand the connection between the Atapuerca karst system and the Duero basin hydrographic incision.

Previous studies dated terraces T3 (+70-78 m), T4 (+60-67 m) and T5 (+50-58 m) by ESR to 1.24; 0.8-0.9 and 0.70-0.6 Ma respectively, in agreement with a paleomagnetism study that revealed normal polarity for terraces T5 (+50-58 m) and T3 (+70-78 m), and inverse polarity for T4 (+60-67 m). However, ESR ages were obtained from the Aluminum center whose results have recently been interpreted as maximum dates because the signal from this center does not bleach completely. In contrast, the Ti center has much faster bleaching kinetics, so it usually provides more coherent ages although it is more complicated to measure.

To complete the previous chronostratigraphic framework of the Arlanzón terraces, eight ESR samples were collected from T2 (+84-88m), T3 (+70-78 m), T4 (+60-67) and T5 (+50-54 m) to be dated using both the Al and Ti centers. Our first results suggest maximum Al ages of Lower Pleistocene for T2 (+84-88m) and T3 (+70-78 m), being impossible to obtain reliable Ti center ages from samples taken in both terraces. Lower Pleistocene terrace T4 (+60-67) was dated using both the Al and Ti center of more than 0.78 Ma. Finally, AZN1502 and AZN1503 from T5 (+50-54 m) yielded an approximate age of Middle Pleistocene. The results provided in this paper are in agreement with the geological context and the previous Al ESR ages for Arlanzón river terraces.

The Upper Volga River formation history reconstructed: a case study of Rybinsk-Plyos valley section

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The Upper Volga – the upstream section of the Volga River – was always considered to have had a long and complex paleogeographical history. Given the extensive research that has been conducted in its valley since the 1930s, one would expect its evolution to be firmly established. Nevertheless, our recent studies prove that previous reconstructions were often operating popular, yet misleading misconceptions. One of such popular misconceptions was the formation of the Upper Volga River system of proglacial lakes during the LGM (MIS2). The Upper Volga valley was considered to have emerged only after this lake system was drained during Late MIS2. It was thought that the geological evidence of the lakes' existence was still preserved in the valley as terraces. To test this concept, we conducted field studies in the valley focusing on three key sites: incision valleys near Tutayev and Plyos (which were thought to have formed during the lake drainage), and the Rybinsk site. We discovered no geological evidence of the proglacial lakes' existence in the valley during MIS2. Instead, luminesce dating revealed that a lot of previously thought fluvial or limnoglacial terraces are in fact comprised of fluvioglacial sediments – we make this assumption since all the ages appear to be overestimated. The incision valleys also seem to have appeared a lot earlier than MIS2: we were able to locate the remnants of the river terrace in the Plyos incision valley dating back to MIS5e. An archive section near Rybinsk also showed that during that time the upstream part of this valley part was taken up by a lake. During Late MIS2, the Rybinsk-Plyos valley section had already existed as a fully functioning river, as indicated by MIS2 river terrace. All of this evidence combined with our assessment of the GIA influence on the Upper Volga valley during MIS2 indicates that 1) the minimum age of the valley formation is MIS6; 2) since MIS6, it was never fully occupied by proglacial lakes; 3) it incised after Late MIS2 and in Holocene, as found river terraces suggest.

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New combined study of surface and subsurface maps of the Turin Plain (Po River)

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Turin and suburbs (NW Italy) lie in the western sector of the Po Plain, between the Western Alps and the Turin Hill. The published data concern the marine and deltaic deformed Pliocene succession and the overlapped (in discordance) fluvial Quaternary sequence separately. The aim of this research is to combine the two information toghether to obtain a unique stratigraphic framework of the Turin subsurface, useful for any significant intervention in the area.
The Pliocene (Zanclean to Piacentian) succession (mailny observed in the lower stretch of some logs with depth between 150 and 16 m and through the geophysical survey) consists of bacinal/outer shelf Argille Azzurre, litoral Asti Sand and deltaic/fluvial Villafranchian sediments. Complex lateral stratigraphic relationships and time-trasgressive boundaries exist between these deposits.
The Pliocene succession setting, involved in the Turin Hill thrust propagation fault system and deformed until the Early Pleistocene, was evidenced by this recent reconstruction of the multilayer structure through the construction of a three-dimensional model based on a database.
The Quaternary sequence (observed in the upper stretch of all logs and by geological and geomorphological survey) lies on a sub-horizontal erosional surface shaped on the Pliocene succession and consists of a relatively thin cover (30-35 m) of outwash gravel, with local sand, forming the proglacial plain of the Rivoli-Avigliana end-moraine system fed by the Dora Riparia catchment basin (Susa Valley). This plain occupied the whole space between Alps and Turin Hill until the Upper Pleistocene, while the Po River was missing from the Turin area as it flowed south of Turin Hill. The new collected data allowed to distinguish two outwash units (Bennale and Turin), separated by a palaeosol and referred to pre-LGM and LGM by radiocarbon dating respectively. Subsequently, this plain was terraced by the Lateglacial-Holocene activity of the Po River and its tributaries (Dora Riparia, Stura di Lanzo and Sangone), that formed a set of entrenched fluvial terraces along this watercourse.
This work combines surface and subsurface cartographies. A new interpretation of the stratigraphic and tectonic relationships between the buried Langhian-Early Pleistocene sedimentary successions and the terraced fluvial deposits lying above them are shown.

Patterns, rates and controls on Quaternary foreland basin erosion along the Sahara Desert margins using fluvial-fan terrace markers

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Foreland basins are subsidence zones that develop onto continental crust by flexural geodynamic processes linked to the growth and decay of collisional mountain belts. The sedimentary and geomorphic records of foreland basins can provide key insights into the patterns, rates and timing of long-term Quaternary landscape development and drivers.

Here, we use an inset sequence of fluvial-fan surfaces to document the long-term erosion of the Ouarzazate Basin (Morocco), a major foreland basin developed along the southern flanks of the Atlas orogenic system and the NW Sahara Desert margins. The basin is 150x40km, is infilled with > 1 km of Neogene-Quaternary sediment and covers an area of ~3200km^2. During the Plio-Quaternary, a switch from foreland sedimentation to erosion occurred leaving behind relict fan surfaces and river terraces formed primarily from streams draining the High Atlas orogen (north) and its Anti-Atlas forebulge (south) regions. The fan surfaces are dissected by ephemeral modern streams exiting the SW basin via a deeply incised canyon across Anti-Atlas basement.

The landform sequence comprises six levels (Q6 = highest, oldest; Q1 = lowest, youngest) spanning the Pleistocene, based on ^{10}Be cosmogenic dating of foreland fan surfaces (Arbolyea et al, Geol Soc.Lond. 2008) and OSL dating of fold-thrust belt fluvial terraces (Stokes et al., QSR 2017; Zondervan et al., Geomorphology 2022). These remnant fan surfaces cover some 1500km^2 (~50%) of the foreland basin area. Older levels (Q6-5) form minor components and are primarily preserved in the eastern basin region with Anti Atlas sources. Q4-Q2 dominate the landform record and reflect High Atlas sources. The youngest Q1 level forms a minor component, dominated by Anti Atlas sources.

Using an SRTM 1-arc second DEM, we interpolate the fan surfaces across the basin. We then use the interpolated surfaces to quantify erosion between different landform levels (sensu Stokes et al., Quaternary 2018). Erosion rates are then calculated using the published age data. We explore some technical aspects of the digital mapping and erosion quantification approaches used. Finally, we discuss the landform patterns, erosion rates and timing in the context of a post orogenic landscape affected by basin-scale river captures.

The subsurface geological map of the Turin metropolitan area (Western Po Plain)

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The 1:100,000 subsurface geological map of the Turin area is the cartographic output of a database-assisted 3D geological model, covering an area of about 890 km^2, between the western Alps and the Turin Hill reliefs. This sector is of strategic interest because it develops above one of the most significant structural elements of the northwestern Apennine - Po plain transition, i.e. the Turin Hill thrust front and associated folds system, whose late Miocene to early Pleistocene tectonic activity strongly influenced the geologic evolution of this region.

In the recent past, the geologic setting and the oldest (late Miocene) activity of the eastern, outcropping part of this tectonic belt were studied and mapped in detail in the Turin Hill. The general traits of the architecture and recent (Plio-Quaternary) activity of the western, buried counterpart of this belt were only partly illustrated by a few seismic reflection profiles. Furthermore, lower detail and scale geological maps of the subsoil of the central-eastern and northern portions of the study area have been provided. Therefore, a complete geological subsurface representation of the tectono-stratigraphic assemblage of the tectonic belt was still lacking.

In this perspective our map is a more detailed document, providing an updated representation of the stratigraphic and tectonic relationships between the buried Langhian - Lower Pleistocene sedimentary successions involved Turin Hill thrust-propagation folds system. The map is grounded on detailed stratigraphic log correlations along triangle meshes, combines subsurface and surface cartographies and includes a contour base map of terraced fluvial deposits (middle Pleistocene - Holocene).

The map illustrates for the first time all the lithostratigraphic units of the stratigraphic succession, their reciprocal conformal or non-conformal relationships and represents in greater detail the tectonic structures, providing new elements to discuss the tectonic evolution of the northwestern termination of the Apennine thrust-and-fold belt. In addition, it provides a reference model and a data infrastructure of the subsoil of the Turin plain, useful for various thematic research with application purposes.

Depositional Sequences of Pelotas Basin (southern Brazil): an accommodation succession view

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Pelotas Basin is located in the southernmost Brazilian Continental Margin. Its onshore portion corresponds to the Pelotas Basin Coastal Plain, which is composed of depositional sequences mainly controlled by glacioeustatic cycles of about 100 kyr, considered as high-frequency sequences. Studies of the Basin approach its filling from depositional sequences of longer period. Recently, a hierarchization was proposed for the sedimentary record of the Pelotas Basin, using the accommodation succession method.

The aim of this work was to complement the stratigraphic hierarchical framework of the Pelotas Basin with the inclusion of an intermediate scale depositional sequence. For this purpose, there were interpreted seismic sections, Ground Penetrating Radar (GPR), outcrops, well data and vertical electrical soundings (VES).

According to previous studies, four composite sequences were established for the Pelotas Basin. Each composite sequence is formed by three sequence sets, defined according to their stacking pattern as Progradational-Aggradational (PA), Retrogradational (R) and Aggradational-Progradational-Degradational (APD). Thus, 12 sequence sets compose the basin filling, and the last sequence set comprises eight depositional sequences. The depositional sequence here identified was correlated with the last depositional sequence present in the seismic sections (depositional sequence 43), with about 0.5 Ma, and is composed of lowstand, transgressive and highstand/falling stage systems tracts. A river mouth to the ocean was interpreted as part of the lowstand systems tract of the depositional sequence 43. With the development of the transgressive and highstand/falling stage systems tracts, this river system became internalized, forming a bayhead delta. The highstand/falling stage systems tract of this depositional sequence (43) comprises the four high-frequency sequences which outcrops in the coastal plain, corresponding to Quaternary barrier-lagoon systems. Each of the high-frequency sequences, in turn, can be subdivided into system tracts.

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Sediment dynamics in a mesoscale catchment. Impacts of geology when using landscape evolution models. A modelling approach for the Northern Franconian Jura, Germany.

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Landscape Evolution Models simulate the transport of sediment over a landscape. Several parameters are used to describe the flow of water on a surface and thereby calculate a change in landscape. However, the transport of sediments in a catchment is a complex system and simplification is needed to keep computing powers reasonable. The CAESAR-Lisflood landscape evolution model simplifies the transition from precipitation to runoff with a cell storage-based system, where water is retained in each cell and released at later iterations, simulating infiltration and forming the hydrograph. This reduced complexity works well for surface processes but leads to problems in catchments, where ground water flow and infiltration are unknown parameters and an unknown proportion of sediment transport is connected to sub-surface processes.

The Weismain River catchment (~125 km^2) located in the Northern Franconian Jura, Germany, poses a particular challenge when modelling the sediment dynamics of the catchment. The Weismain river and its tributaries are deeply incised into a limestone plateau forming small, well-defined valleys opening to wider floodplains in the lower parts of the catchment, where sandstone is dominant. The karstic nature of the catchment and its resulting irregular groundwater flow complicates the model calibration and lowers confidence in model results. To get a better understanding of the sediment dynamics and the evolution of this catchment, we first need to determine the impact of the karstic geology on model results. Therefor we are using the CAESAR-Lisflood model not only with precipitation inputs but also with inputs from springs. We are now looking at the spatial distribution of alluvial sediments and how they are affected by differences in discharge calculations. This should give insight into the sediment dynamics of the catchment and should help gain confidence in future model results.

Evolution of the Vosgian fans in the Upper Rhine Graben during the Upper Pleistocene and the Holocene : an history controlled by pre-existing landforms, Rhine river and climate fluctuations

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The Upper Rhine Graben is a large Cenozoic structure that is still active today and drained by the Rhine river along about 250 km of its course. Its margins are characterised by large alluvial fans, several tens of square kilometres in size, deposited by the rivers draining the bordering mountains (uplifted blocks), i.e. the Vosges (west) and the Black Forest (east). Composed of pebbles and sands, these fans were mapped in the southern quarter of the graben using aerial photographs and test pits during the production of geological maps in the 1960s and the 1970s. They were attributed to the Upper Pleistocene on the basis of their topographic position and the weathering degree of the coarse materials, but numerical age estimates were missing so far. It was therefore difficult to identify the drivers of their formation.

Here, thorough gearchaeological survey allowed exploiting numerous excavations dug in four large fans deposited by four main Vosgian rivers (i.e. Thur, Giessen, Bruche and Zorn) to reconstruct their evolution during the Upper Pleistocene and the Holocene. About twenty stratigraphic profiles (several metres long and up to four metres deep) have been dated by luminescence, radiocarbon and archaeological findings. Combined with the study of LiDAR-derived DEM, our results show that the formation of these fans is primarily controlled by the pre-existing landforms and by the lateral mobility space of the Rhine, which determines their maximum extension. The fans were mainly deposited during the first part of the last glacial period before being incised and covered by aeolian deposits, silts and sands. This points to a decrease in fluvial discharges and flow capacities after 22 ka. After coarse deposition attributed to the end of the Upper Pleistocene, a luvisol developed from the Lateglacial period onwards. From the 1st millennium BC onwards, this soil is truncated by locally coarse torrential deposits that have been so far wrongly attributed to the Weichselian. In the end, on a regional scale, fans evolution appears to be controlled by the climate and the relief. However, a better spatial resolution and deeper profiles are needed to re-evaluate the role of neotectonics.

Post-glacial fluvial evolution of the Cleurie Valley (Vosges Mountains, NE France): a complex story

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The Vosges Mountains are located in NE France and belong to the Variscan low-mountain ranges sprawling across the alpine foreland. Abundant and widespread glacial features imprint the landscape in the more elevated southern part, especially thick sedimentary sequences filling the deeply incised valleys. Located at the heart of the formerly glaciated area, the small Cleurie catchment (~80 km²) stands out because (i) it hosted a large (or several) palaeolake(s) (supposedly) during the peak of the last glaciation due to the singular convergence of three individual valley glaciers and (ii) ~40% of the catchment's surface is still covered by glacial-related deposits. Although several works previously investigated this advantageous but challenging setting, some of their results are outdated (e.g. geomorphological mapping) and, more importantly, none of them focused on the post-glacial landforms and provided chronological constraints.

This study thus aims to reconstruct the post-LGM evolution of this valley. It thus combines morphometrical analysis at the catchment scale with geomorphological, sedimentological and chronological analyses of the fluvial morpho-sedimentary units, including the modern riverbed, in the main valley. First, we took advantage of a 1m LiDAR-derived DEM and high-resolution geological mapping to produce updated geomorphological maps. Second, longitudinal analysis involved the extraction of river profiles and *in situ* grain-size measurements of the modern coarse bedload. Third, grain-size measurements and luminescence profiling via a portable reader on the fine-grained fraction of two representative profiles, along with radiocarbon dating of woody macro-remains (e.g. trunk), were performed. Geomorphological analysis highlights a system of two widespread terrace levels above the modern floodplain. Dating of the upper terrace, unconformably overlying lacustrine deposits, possibly allocates the first post-glacial aggradational event to the Bølling-Allerød or the Younger Dryas whereas floodplain formation can be assigned to the final part of the Holocene (Subatlantic). Moreover, (i) the Cleurie's long profile exhibits two major knickzones, (ii) tributaries' profiles are either concave, straight or convex, (iii) and the riverbed grain size increases downstream. These features together with post-glacial readjustments involving river incision and terrace formation point to a transient fluvial response in the catchment, which is unique at the massif scale.

A case study of effect of tectonic uplift and precipitation on the formation and evolution of alluvial fans at the northern foot of Qilian Mountains

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As an achieve for recording past regional environmental changes, alluvial fans have received widespread attention from the earth science community. Tectonic activity and climate change are generally considered to be the two main factors affecting the development of alluvial fans. The Qilian Mountains, located on the northeastern edge of the Tibetan Plateau, have experienced intense tectonic uplift since the Cenozoic. Mountain rivers flow down the great difference in elevation between the surrounding mountains and the Hexi Corridor and form a series of alluvial fans which can be studied comparatively in this region at the northern foothills of the Qilian Mountains. To explore the effects of precipitation and tectonic uplift on the formation and development of alluvial fans, a numerical model of the drainage-fan system was developed based on the stream power law and the diffusion equation. Simulations of the Xigou and Dayekou rivers and their alluvial fans in the Qilian Mountains were carried out using the above numerical model. The results show that changes in precipitation and uplift rate both affect the fan landform characteristics. Both an increase in uplift rate and a decrease in precipitation lead to an increase in fan slope and vice versa. The fan slope varies linearly with the uplift rate, while the effect of precipitation on the fan slope is relatively small. The response of catchment to tectonic activity and precipitation disturbances, as the change of sedimentary flux, is also in different patterns.

Architecture of Late Pleistocene to Holocene outwash plain and its environmental implications (the Tatry Mts., Slovakia)

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We have studied an areally restricted, gravelly outwash plain deposited in front of the Studena Valley (Tatra Mountains, Carpathians), which was glaciated during the Late Pleistocene. The plain deviates from common proposed models for outwash plains/fans by lacking proximal to distal trends of deposits and different architectural elements. The lower and middle part of the 9 m thick outwash succession is typified by high facies variability and only locally preserved small bedforms. The lower part of succession shows three cycles (units I-III) with OSL ages from 77.7±8.1 to 23.2±1.3 ka. Each cycle consists of channelized, upward-fining sediments at the base overlain by horizontal, low-angle or disorganized tabular gravelly beds. Occasional sand lenses show parallel lamination and antidune stratification. The cycles are overlain by disorganized gravel with locally preserved dune stratifications capped by massive sand and silty mud showing pedogenic modification (unit IV). Preliminary OSL data from the top of the unit yielded 13.6±1.0 ka. The overlying unit V consists of disorganized gravel with clusters of cobble- and boulder sized clasts and boulder-sized rip-up clasts. The boundary between units V and VI is dated by OSL and ^{14}C to 10.8±1.3 ka and 11.361 cal., respectively. The unit shows wide and shallow channels with lateral accretion packages suggesting meandering rivers. Vertically, and also laterally these channels pass to gravel filling small channels and sand lenses. The entire succession is capped by pebbly sand overlain by a Holocene palaeosoil and a current soil (unit VII).

The sediment architecture points to deposition by stream and hyperconcentrated flows at the base of each unit I-III (channelized geometry) passing to deposition by prevailingly hyperconcentrated flows (sheet geometry). The units contain supercritical flow structures suggesting a high discharge variability system. The interval of fine sand and mud at the top of unit IV preliminarily dated to 13.6 ka suggests calm deposition during warmer phase (Bölling/Alleröd?). Preliminary interpretation associates the areally extensive deposits of unit V to deposition by hyperconcentrated flows possibly triggered by sudden drainage of an ice-dammed lake. The occurrence of meandering rivers in unit VI indicates changed conditions at the onset of the Holocene.

Quaternary alluvial terraces identification and analysis in the central Marche region (central Italy) for climatic and tectonic signals detection purposes

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River terraces, together with their deposits, can provide a great deal of information about the history of a drainage system, from a hydrological and sedimentological perspective. As such, they are functional to understand the influence of tectonics, varying climate and base level change on landscapes, and their relevance as geomorphic markers is widely recognized. Through the complete and accurate analysis by remote sensing and field work of the Marche drainage network, it has been possible to identify and reinterpret the main river terrace staircase and to map its remnants in detail, in the perspective of attempting the detection of the tectonic and climatic signals preserved in these geomorphological features.
The selected area is challenging from a geomorphological and geomorphometric standpoint because it is characterized by low-rate tectonic activity and well-preserved fill terraces, that developed from the Upper Pliocene-Lower Pleistocene, allowing to analyse these classic climatic signal-bearing forms in a tectonically active setting. The fill terraces will be measured and dated, and then the data will be interpreted with methodologies already implemented by other authors, that will accurately prevent eventual biases in the analysis. This work was based on a relatively innovative approach, that analyses Relative Elevation Models (REMs), converted from 1 m/pixel DEMs collected from a 1x1 LiDAR dataset, to better pinpoint river terraces through the identification of their surfaces with the SCM model. Further goal of the research is to verify if there is a possibility to isolate a clear climatic signal, despite the tectonic influence on the area.

Deciphering long-term river incision in the Middle Rhine Valley (Germany) by Electron Spin Resonance dating of quartz

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Connecting the Alps with the North Sea, the Rhine river system represents one of the most complete sequences of fluvial archives at the continental scale. The Middle Rhine Valley (MRV) exhibits a well-preserved terrace flight that serves as an important record for studying the response of geological and sedimentary processes to the impact of changing environmental conditions. However, reconstructing rates of landscape evolution over the Late Cenozoic period remains challenging mainly due to difficulties in dating such ancient terrace sediments and the resulting lack of numerical age available. For the first time, we use electron spin resonance (ESR) to date quartz grains from three various localities corresponding to two key geomorphological markers in the MRV's staircase. They are the Kieseloolithe terrace, i.e. oldest level in the sequence (Ochtendung), and the upper and lower levels of the main terrace complex sampled at Kärlich and Kasbach-Ohlenberg, respectively. Based on these new ESR data derived from the Multiple Centre (Al & Ti centres) approach, we aim to (i) assess the time-varying incision rates over the Late Cenozoic, (ii) unravel the role of each driver responsible for the disequilibrium of the Rhine on these timescales, (iii) and discuss potential implications as far as early human occupations in the region.

Al and Ti ESR signals resulted in consistent equivalent dose (De) values, suggesting [MD1] complete bleaching (=signal reset) prior to deposition. First ESR age constraints are stratigraphically consistent for each terrace. The main terrace complex yield age estimates of ~1.3 Ma (older main terrace, Kärlich) and ~1.15 Ma (younger main terrace, Kasbach-Ohlenberg). In comparison, the Kieseloolithe terrace deposits at Ochtendung shows a much older age estimate of at least ~1.8 Ma, which is consistent with the existing geomorphological framework, although perhaps somewhat younger than the expected Pliocene chronology. Preliminary age constraints of the Middle Rhine terraces suggest low incision rates of <0.5 mm/yr for the period from the onset of the Quaternary. Finally, our results also indirectly provide additional chronological constraint to the deposits associated to the well-known Kärlich archaeological site, considered as one of the earliest evidence of human presence in western Germany.

The palaeoenvironmental evolution of Privlaka pedo-sedimentary complex on the Adriatic coast, Croatia – preliminary results

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The pedo-sedimentary complex of Privlaka is situated in the central part of the Eastern Adriatic coast, in Croatia. The investigated section is represented by a more than 12 m thick succession of glacio-fluvial deposits and palaeosols. During the Pleistocene sea-level low stands, the area of Privlaka was influenced by terrestrial and glacio-fluvial sedimentary processes presumably originating from the East. The investigated succession was divided into four different units. One is represented by palaeosol (the lowest unit), while the others are represented by glacio-fluvial deposits divided by an indication of sedimentation under different environmental conditions. Aiming at identifying and describing the palaeoenvironmental evolution of the abovementioned site, a detailed investigation is being carried out. The investigation of palaeoenvironmental changes on the Privlaka section is conducted by high-resolution analysis using a multi-proxy approach comprising chemical analysis, particle size analysis, modal analysis, pedological analysis, bulk and clay mineralogical XRD analysis, as well as micromorphological analysis of soil thin sections. The lateral extent of the described units was obtained by the application of geophysical methods and remote sensing techniques, while the chronological framework of the complex is established by optically stimulated luminescence (OSL) dating. This research is funded by the Croatian Science Foundation under the project ACCENT (IP-2020-02-3274).

Periglacial features and permafrost disappearance during MIS-2 in northern Poland and northeastern Germany

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Some landscape features of lowlands in Northern Poland and Germany represent relicts of former periglacial activity. These features include ice wedge casts, polygons and other surface patterns, cryoturbation structures, pingo scars and thermokarst features. Recent studies of the areas covered by the last glaciation indicate that the disappearance of permafrost under the ice sheet was not complete, and even that it was limited only to the subglacial water circulation zones and the importance of subglacial permafrost in the formation of subglacial drainage and subglacial channels. The most important features include thermal contraction cracks, oriented kettle holes on outwash plains, permafrost-affected horizons in soil profiles, as well as the long-term preservation of buried dead ice blocks in depressions.

Three main lake generations of the appearance were recognized: 1. “early” pre-Allerød lakes, 2. lakes of the Bølling-Allerød period and 3. “late” Preboreal generation of lakes. In the context of the final permafrost decay, the lakes of the youngest, Preboreal generation are particularly important, since the lakes age differentiator was the varied length of preservation of lake basins by buried dead ice blocks, which in turn was dependent primarily on the conditions of surface drainage network. Under the permafrost conditions, full preservation of dead ice blocks took place when the mineral cover reached the thickness corresponding to the depth of the active layer. In this way, buried dead ice blocks became an essential element of the permafrost. Under thermokarst, at the places where dead ice blocks existed, quickly spreading taliks formed.

In the last glaciated area are some local evidences of periglacial features, like meso scaled ice wedges pseudomorphs and active layer based ball-and-pillow graviturbations, showing clearly the retreat of discontinious permafrost during Younger Dryas period. The preservation of dead-ice masses in some local depressions until the Preboreal leads to the conclusion that the ultimate disappearance of permafrost in the study area occurred at the beginning of the Holocene.

The research was supported by the National Science Centre of Poland NCU.

Digital terrain model DTM 5.0 usage in engineering geological mapping and analysing of the development of the landslide near Machnac Hill in Biele Karpaty Mts.

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"Identification, inventory and engineering geological mapping of slope deformations", is geological task solved by the State Geological Institute of Dionyz Stur. In the scope of this project the digital terrain model DTM 5.0 generated from the airborne laser scanning in 2018 has been widely used. The LiDAR technology has significantly improved the quality of mapping of the slope failures and possibilities to precisely analyse terrain surface. Identified slope deformations are then verified and documented during field surveys.

During the field survey in May 2020 an active landslide situated northeast of the Machnac Hill in the Biele Karpaty Mts. was documented. This part of the mountain range is built of flysch rocks environment which is significantly endangered and affected by slope deformations. All morphological features characteristic for the surface of an active landslide area were documented at the site.

An unmanned aerial vehicle was used to create the second set of airborne laser scanning of the active landslide surroundings in November 2021 during leaf-off conditions. The scanning was realised in the cooperation with Geotronics Slovakia Ltd. and the Department of Surveying. This survey provided an updated DTM 5.0 model with a time gap of 3 years.

Interpolated LiDAR data comparison of the two differential digital terrain models via geometric analysis was used for the elevation change detection in a form of differential map. A colour scale was used to illustrate landform changes as the result of the mass movement. Depletion of material in the crown and its accumulation in landslide toe are clearly visible in difference map.

Post-Late Glacial Maximum costal evolution of the north Sardinia

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The integrated use of Side Scan Sonar (SSS), Multibeam (MB) and ground truth points acquired with Remote Operating Vehicles (ROVs) are helpful tools to map and describe seabeds laying at different water depths. In this view, marine mapping can provide important information on the underwater sedimentary bodies deposited as consequence of past sea level changes.

According to this, latest Pleistocene beach ridges, if analized in term of spatial continuity, depth and age formation, may point out which have been the relative sea level rise steps occurred post Late Glacial Maximum. Beach ridges were therefore mapped in different areas of northern Sardinia, and their spatial distribution was reconstructed using the GIS (Geographic Information System).

In this work, we present the seabed map of the Tavolara Marine Protected Area (MPA). Using a marine mapping survey, we reconstructed the paleogeography of the area surrounding Tavolara Island during the interval from the Late Glacial Maximum (LGM, 20-19,000 y BP) to the Present. Paleoshorelines and associated beachrocks were identified at depths of -90, -70, and -50 m, along with the presence of interpreted paleo-rivers, paleo-lagoons and paleo-delta systems.

The reconstruction of the paleo-shorelines distribution let us to relate the beach ridges laying at -90 m, -70 m -50 m depth, respectively, to the relative sea level still stand occurred after the Melting Water Pulse (MWP) 1A (14,650 y BP), to the relative lowstand occurred during the cold Younger Dryas (between 12.900 and 11.700 y BP) and to the so-called “8.200-kiloyear cold event” following the MWP 1B.

The geological structure of Italian seas: a synthetic and up-to-date GIS representation of tectonic and volcanic features around Italy (Mediterranean Sea)

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An updated structural map of Italian seas is represented at 1:1,250,000 scale. The map is the result of cooperation between marine geology researchers from different universities and research institutes coordinated by ISPRA-SGI, in the framework of the European Marine Observation and Data Network (EMODnet) Project Lot Geology. The map aims to present in a synthetic but exhaustive way the structural setting of Italian seas, a key region in the geological setting of Mediterranean Sea. This area, geologically very active, is dominated by the geodynamic process of convergence and collision between the European and African plates, which during the Quaternary recorded tectonic activity accompanied by seismic and volcanic events of great impact.

The map shows the geological expression of the seafloor surrounding the Italian region as revealed by the marine geological researches carried out during last thirty years that have benefited from the contribution of relevant technological innovations in the field of marine geological surveys (multibeam, sub-bottom CHIRP, high penetration seismic surveys).

The map contains structural data from original surveys as well as data from scientific literature or derived from strategic national research programs, properly integrated and validated in order to create a homogeneous data set for the mapped area.

A geodatabase is related to the Map, in which the structural and volcanic elements have been classified according to the EMODnet terminology (INSPIRE compliant) and characterized by geometric, kinematic and chronological parameters.

The tectonic structures and the volcanic elements are represented on a bathymetric DTM downloaded from the EMODnet Bathymetry portal and the tectonic topic is complemented by additional information on seismicity, heat flow, crustal thickness, thickness of the Plio-Quaternary deposits.

The map shows the current geological-structural setting of the Italian seas, the migration over time and space of the tectonic events, those features that have contributed mostly to the current conformation of the Italian seafloor and, among these, those that may originate geohazards.

Therefore, the map represents a solid base for more detailed studies of seismotectonics and applied geology for territorial management and spatial planning as well as for scientific dissemination which will benefit the new generations of marine geologists

The process of update of the structural map of Italian seas

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The Geological Survey of Italy – ISPRA coordinates cooperation among marine geology researchers from different universities and research institutes, in the framework of the European Marine Observation and Data Network (EMODnet) Project Lot Geology.
The cooperation is aimed at providing products for the "Geological events and probabilities" layers of the Project including earthquakes, volcanoes, landslides, tectonics. Data gathered during this work allowed to realize an update of the structural map of Italian seas at 1:1,250,000 scale.
The map shows the geological expression of the seafloor surrounding the Italian region as revealed by the marine geological researches carried out during the last thirty years that have benefited from the contribution of relevant technological innovations in the field of marine geological surveys (multibeam, sub-bottom CHIRP, high penetration seismic surveys).
The map contains structural data from original surveys as well as data from scientific literature or derived from strategic national research programs, properly integrated and validated in order to create a harmonized data set.
Structural and volcanic elements, classified according to the EMODnet terminology (INSPIRE compliant), are characterized by geometric, kinematic and chronological parameters which are included in the geodatabase completing the map.
The tectonic structures and the volcanic elements are represented on the EMODnet Bathymetry DTM and are complemented by additional information on seismicity, heat flow, crustal thickness, thickness of the Plio-Quaternary deposits.
The map aims to present in a synthetic but exhaustive way the structural setting of Italian seas, a key region in the geologically very active Mediterranean Sea which is dominated by the geodynamic process of convergence and collision between the European and African plates.
The map shows the current geological-structural setting of Italian seas, the migration over time and space of the tectonic events, the features that have contributed mostly to the current conformation of the Italian seafloor and, among these, those that may originate geohazards.
The map represents a solid base for more detailed studies of seismotectonics and applied geology, for territorial management and spatial planning as well as for scientific dissemination.

Mapping Quaternary travertine of the Viterbo geothermal area

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The Viterbo thermal field (more than 50 small hydrothermal vents) corresponds to a deep uplifted calcareous structure (horst) bounded by a complex Plio-Quaternary extensional fault system. This area insists on a large volcanic plateau produced by the emplacement of eruptive deposits from three volcanic districts (Cimino, Vico and Volsini), active between 1,35 Ma e 90 ka. The volcanic and Quaternary sedimentary units rests on Pliocene clays and sands of the Tiber River graben and on Triassic-Eocene thrust folds units ("Tuscan ", "Umbrian", and "Ligurian"). The thermal mineralized water upwelling along the main structural discontinuities, (produced by polyphasic tectonics and by volcano-tectonic activity) built small, low relief bodies of rather compact, well-bedded porous carbonate rock mainly made of macro, micro crystalline and microbial facies. The macro crystalline carbonate commonly occurs surrounding the main spring vents (punctual venting shield/crater mounds, or fissure ridge, result from physico-chemical processes (cooling, evaporation, etc.). and flow velocity. Microbial laminites, result from biologically mediated processes developed by microbial communities, commonly spread on the thermal distal drainage system that is a complex environment comprising swamps/palustrine flats and slopes or shallow lakes filled with mixed ambient and thermal water. The morphological analysis of these bodies has been integrated with digital models of the terrain (DTM), historical topographic maps, aerial photos and high-precision photogrammetry models obtained from UAS flights (with the support of GNSS stations for a precise spatial location). To define the structure and morphology of these deposits and the organization of their depositional system, geological surveys and facies analysis have been combined with passive and active seismic techniques and other geophysical data directly or indirectly related to them. The data are organized in layers and integrated into a GIS project. The numerical cartography (CTRN) and the Geotopographic database (DGBT 2009-2014) of the Latium Region have been used as a basic map. All these data were integrated with other layers: geodetic and photogrammetric information location and chemical-physical characteristics of the thermal mineral springs; geological and structural data; borehole, etc. Finally, historical and archaeological data have also been considered since these springs were exploited since Roman and Etruscan times.

Quaternary map and evolution of the Tyrrhenian side of the Northern Apennines: preliminary results from the METIQ Project

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The METIQ Project aims to produce a 1:500.000 scale Quaternary Map of Italy, which synthesizes the Quaternary evolution of the Tyrrhenian side of the Northern-Central Apennines (Liguria, Tuscany, Umbria, Latium, and Abruzzi regions). The Quaternary Map is the result of the integration of different source data spanning from the 50.000 and 100.000 scale National Geological Maps of Italy, the 1:250.000 scale Geological Continuum project and, where available, the Regional Geological Maps at 1:10.000 scale. All these data were then compared to and harmonized with the geological maps available in the more recent scientific literature.

The Map includes the main lithological, chronological and paleoenvironmental evidence through the time of the Quaternary deposits reflecting the complex interaction between climate and tectonics. Quaternary sedimentation onset in an ongoing extensional regime in the inner (western) sector of the Apennines whereas the compressive fronts were active to the east. The distribution of Quaternary deposits on the Tyrrhenian side of the chain depicts this scenario meaningfully showing a succession of sedimentary basins from the coast to the axial part of the chain. The westernmost basins are characterized by several cycles of shallow-marine and continental deposition accommodated into extensional basins and, at least across a Tuscany transect, moving to the axial part of the chain, by continental deposition within intermontane basins that experienced the transition from compressional to the extensional regime with a progressive rejuvenation toward the east. In Latium-Abruzzi Apennines, the current extensional tectonics is clearly shown by the stack of Quaternary tectonic terraces and confirmed by strong historical and recent earthquakes.

The coastal area is dominated by large fluvial plains slightly subsiding and filled with alluvial deposits. The main features come from the interaction, during the Quaternary, between tectonics and isostatic and eustatic sea level variations, leading to the creation of marine terraces along the coast.

The coexistence of fully extensional sedimentary basins in the inner part of the chain and compressional-extensional basins in the axial part of the orogen is more evident across the southern part of Tuscany whereas to the north (Ligurian-Emilian Apennine) is less pronounced possibly reflecting a deep crustal discontinuity.

Mapping continental quaternary deposits of mountainous areas: the high Orta Valley (Central Apennines, Italy)

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The preliminary results of the Quaternary geological surveys performed along the high Orta Valley in the frame of the CARG – Project (Geological Map of Italy 1:50,000 Sheet 370-Guardiagrele) are here presented.

The high valley of the Orta River extends in the outermost sector of the Central Apennines, between Caramanico Terme to the north and San Leonardo pass to the south, within the UNESCO Maiella Geopark. It is a narrow depression, N-S trending, confined between the calcareous ridges of Mount Morrone to the west and of Maiella Massif to the east and floored by late Neogene siliciclastic foredeep deposits. The Quaternary valley infill consists of clastic deposits deriving from the erosion of the steep slopes of the Maiella and the Morrone.

The oldest continental deposits are diamicton containing metric boulders and abundant silty-sandy matrix (megabreccias) referable to catastrophic rock-slope failures, presumably occurred in the Early or early-Middle Pleistocene during the first stages of the Orta Valley development. These deposits, now forming isolated reliefs, were initially confined in valley trunks among siliciclastic lithotypes and were later exposed by erosion giving rise to a relief inversion.

The valley's eastern and western flanks are characterized by several generations of Middle to Late Pleistocene slope and proximal alluvial fan deposits, shaping wide piedmont wedges. These deposits comprise angular to sub-rounded clast-supported stratified breccias, usually well-cemented and open-work, often covered by Holocene colluvial and talus deposits.

In the axial sector of the valley two orders of fluvial terraces were recognized. The oldest one consists of well-cemented, clast-supported coarse grain gravels underlying a terraced surface 40-50 m above the current thalweg. The younger one is represented by an erosional surface 15-20 m above the valley floor, carved in both the Late Pleistocene slope deposits and the conglomerates of the first order fluvial terrace. They could be referred to the Late Pleistocene and Holocene, respectively.

In such a difficult context, characterized by few available chronological constraints, the integration of stratigraphic and facies analysis with geomorphological and topographic analysis allowed us to define the succession of sedimentary events and their possible correlations with past tectonic and climate conditions.

3D mapping in a 2D country: a new geological map of the Kingdom of the Netherlands

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On the occasion of its centennial anniversary, the Geological Survey of the Netherlands created a new geological map of the Kingdom of the Netherlands. Unlike its predecessor from 1975, this map does not only include the onshore and offshore European Netherlands, but also the Caribbean part of the Kingdom (the islands Aruba, Bonaire, Curaçao, Saba, Statia, and St. Martin). Besides near-surface Quaternary deposits and older rocks, important fault lines and lines of maximum ice extent during glacial periods are shown. Four cross sections illustrate the relation between the shallow and deeper subsurface.

The map, on a scale of 1:600,000, summarises part of our present subsurface knowledge and aims to illustrate the rich geological history of the Kingdom to professionals and the general public alike. By applying a profile-type legend, describing unit sequences rather than just the top unit, we are able to show information from our 3D digital mapping programme on a 2D map. It gives maximum insight into the geological history of the country and clearly demonstrates the occurrence of similar deposits on both sides of the current coastline. One of our biggest challenges was to construct a harmonised legend respecting the diversity of the onshore and offshore geology, yet simple enough to be readily understandable.

From an applied perspective, the map highlights geological resources and geohazard potential. For example, it shows shallow marine sand and gravel resources necessary for offshore construction activities and coastal maintenance. From a geohazard viewpoint, two of the Caribbean islands are dominated by active volcanoes. Furthermore, all islands reside in a tectonically active area and are prone to coastal erosion, flooding and landslides.

The map forms the basis of the Dutch contribution to international projects like the International Quaternary Map of Europe (IQuaME 2500) and the European Marine Observation and Data network (EMODnet). It is also the starting point of renewed and intensified mapping of the Caribbean islands. Finally, this map -both available on paper and interactively online- helps the Geological Survey to market state-of-the-art digital subsurface models that might be very suitable for resource and risk analysis, but difficult to understand.

Mapping a complete silicic and effusive Quaternary volcano: Geo-volcanological map of Monte Amiata (Southern Tuscany, Italy)

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The poster presents the new map of Monte Amiata Volcano (305–231 ka; Italy), at the scale 1:25.000, that perfections the volcanological studies on this Quaternary volcano performed by the authors. Monte Amiata is a rare example of completely effusive silicic (trachydacite) composite volcano. As mapping procedure, we first used the lithostratigraphic units for the identification of the volcanic bodies and their cartographic representation. Subsequently, we applied the UBSU criteria to group lithostratigraphic units into synthems and subsynthems on the basis of the identification of significant unconformity within the stratigraphic sequence. We applied the Unconformity Bounded Stratigraphic Unit criteria, volcanic facies analysis, and structural survey to unravel Monte Amiata geological evolution and volcanic architecture, and to infer the interactions of the regional tectonics with the volcanic plumbing structure. Based on the occurrence of a first-order geological unconformity (representing an intravolcanic paleoweathering surface of regional paleoclimatic significance), we recognized and mapped two major volcanic stratigraphic units and seven phases of volcanic activity. The interpretation of the genetic and emplacement processes of the volcanic deposits is based on the description and distinction of the various volcanic lithofacies within the 40 identified and mapped lithostratigraphic units. Lithostratigraphic units often contain various members (different lithosomes, as lava flow succession, domes etc..) and were correlated across the volcano slopes on the basis of: (i) the observable lateral continuity of the lava flow horizons and bounding surfaces, (ii) the physical volcanology of lava flows (internal and surface structure, texture, geometry and architecture), and (iii) their specific petro-chemical composition. In addition, facies analysis and morphostructural features enabled us to suggest the source location. Based on these data, we have determined a relative chronology of the volcanic events and correlated the extrusive activity on the entire mapped volcanic edifice. As cartographic support we used the topographic map at the 1: 10,000 scale of the Technical Map of the Tuscany Region.

Quaternary glacial GIS database of the South-Eastern European Alps and Northern Dinaric Mountains

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The glacial history of the South-Eastern European Alps and the neighbouring Northern Dinaric Mountains has been studied since the late nineteenth century. However, some discrepancies exist among palaeoglaciological data and maps of this area produced by different authors. Here presented GIS database of glacial evidence has been created with the aim of improving empirical palaeoglaciological reconstructions as well as chronological correlations across mountain glaciations in this region. This GIS database is a compilation of all published glacial and other relevant data in the South-Eastern Alps and Northern Dinaric Mountains in Slovenia, Italy and Croatia. The database contains the following elements: glacial landforms, non-glacial landforms relevant for the interpretation of the glacial environment, outcrop locations, geochronological data, and geophysical survey data. The attribute tables that accompany these elements provide more detailed information about each feature. This includes the type and description of a landform, its assumed age, reference, and relationship to other records in the database. The GIS database has been created in three steps. First, the data were digitised, georeferenced and cited accordingly. Second, the input data were revised in the field and, where necessary, topographically adjusted using a high-resolution lidar-based digital elevation model. Third, the GIS database was used to develop the web map viewer, which also displays empirically reconstructed ice limits for different time spans during the last glacial cycle. The data stored in the GIS database is available in ESRI shapefile format. Both the GIS database and the Web Map Viewer are freely accessible. The collected and generated data have the potential to be used for validation of numerically modelled glacier simulations and more generally for further reuse in the scientific community.

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Seawall impacts on vegetation and carbon sequestration at Gibraltar Point, UK

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Coastal salt marshes are important environments that provide vital ecosystem services such as carbon sequestration, coastal protection, and habitat provisioning. However, salt marshes are increasingly threatened by sea level rise, reduced sediment availability and anthropogenic activity (e.g. embankments). Gibraltar Point National Nature Reserve (GPNR), is a highly dynamic sand spit-enclosed coastal salt marsh that is expanding into new salt marsh areas. However, the installation of the sea defence “Bulldog Bank” in the late 19th century has disrupted salt marsh succession, and a freshwater marsh has developed behind this seawall. While the embankment has created diverse freshwater wildlife, seawalls such as this have detrimental effects on the coastal protection and carbon sequestration capacity of salt marshes. Therefore, this project aims to reconstruct the marsh development to determine the impacts of the seawall on vegetation and carbon sequestration. To address our research aims we collected sediment sequences from the Freshwater marsh and the Old salt marsh habitat and applied a multiproxy palaeoecological approach of grainsize to identify transitions in marsh formation and ontogeny, and pollen to reconstruct past vegetation, loss-on-ignition (LOI) and isotopic and elemental organic carbon and nitrogen to consider carbon sequestration and origins. The preliminary results from the Old salt marsh core show the expected developmental trajectory of a salt marsh habitat, dominated by classic salt marsh vegetation (Amaranthaceae taxa) and organic carbon sources of marine origin, as expected. The Freshwater marsh habitat developed into its modern state when cut off from tidal exchange due to the construction of Bulldog Bank. A decrease in grainsize fractions, stall in carbon sequestration, and increase in freshwater inputs of organic carbon are characteristic of isolation from seawater inundation. Prior to Bulldog Bank the habitat supported a mixture of freshwater (Cyperaceae) and salt marsh vegetation (Amaranthaceae) and organic carbon sources of both marine and fresh origin. Following the installation of Bulldog Bank, peaks in Amaranthaceae pollen suggest breaches in the sea wall. The creation of Bulldog Bank has decreased the influence of marine sources of carbon, sediment deposition, and salt marsh vegetation and thus threatens the coastal protection provided by this salt marsh system.

Recent increased loading of carbonaceous pollution from biomass burning in the Baltic Sea

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Black carbon (BC), spheroidal carbonaceous particles (SCP), and polycyclic aromatic hydrocarbons (PAH) are carbonaceous pollutants affecting the climate, environment, and human health. International regulations limit their emissions, and the present emissions are followed by monitoring programs. However, the monitoring programs have limited spatio-temporal coverage and only span the last decades. We can extend the knowledge of historical emission rates by measuring pollution levels in radiometrically dated marine and lacustrine sediment sequences.

Here we present measurements of BC, SCP and PAH from a sediment sequence sampled in the Öresund strait, between Denmark and Sweden and dated back to CE 1850. Our data show a massive increase in the burial rates of all measured pollutants starting in the 1940s. The pollution deposition peaked in the 1970-the 1980s and declined through the 1990s. However, the declining trend was reversed in the 2000s. Source appointment of PAHs shows a relatively higher contribution of emissions from wood-burning since CE 2000. This coincides with a change towards increased use of biomass for both municipal and regional energy production in Scandinavian. In Sweden, biomass energy use increased massively in the 1990s and supplied 99PJ of energy in 2014, which accounted for about half of the total district heating energy use. Installation of domestic wood burning (pellets) stoves increased from 300 to 11000 per year between 1998 and 2004. Our results demonstrate that changes in energy production to increased reliance on biomass, particularly wood fuels in Sweden, have caused increased the delivery of carbonaceous pollution to marine environments. The increase in particle emissions from wood burning is potentially posing a future environmental and health risk.

Climate variability and anthropogenic impacts through a palaeo-morphological lens: an innovative microCT approach using Baltic Sea benthic foraminifera

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Human-induced impacts are increasing pressure on coastal ecosystems, particularly on benthic ecosystems in high-latitude regions. It has become evident that three of the greatest marine environmental challenges related to anthropogenic activity are warming, ocean acidification, and deoxygenation. The effect of these environmental changes on our uncertain future has created a need to understand their severity and potential outcomes, and geological records can provide a much-needed perspective of environmental processes extending beyond the instrumental period. Within palaeoceanography, marine microfossil species distribution and geochemistry have long been used as proxies for reconstructing environmental changes. Here, we explore an alternative avenue by using calcareous foraminiferal shell morphology (e.g., shell volume, shell thickness, pore density) to study past coastal environments. We have performed tomographic X-ray microcomputation analyses on foraminifera for three-dimensional (3D) shell reconstruction from different sites and periods (e.g., the last 200 years, and the last deglaciation from ~18 to ~11 ka BP into the Holocene) in the Baltic Sea region. These data are combined with conventional faunal analyses of the foraminiferal fauna. We will discuss the advantages, challenges, and future prospects of micro-computed tomography and 3D imaging, how the field has developed over time, and how to manage massive data in the environmental sciences.

Study of geomorphic change by understanding the spatial distribution of late Quaternary sediments using UAV-SfM method, Shichiri-Nagahama coast, northeastern Japan

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Shichiri-Nagahama coast in northeastern Japan has well-exposed sea cliffs with Tertiary and late Quaternary sediments because a harbor was built there in the 1990s, intercepting coastal drift sand. In this study, the spatial distribution of exposed sediments and contemporary landforms is analyzed by UAV-SfM method in order to reconstruct of the Mid Holocene sea-level and assess the process of sea cliff retreat. The sea cliffs in the study area are composed of unconsolidated sedimentary rocks, gravels and sands (marine terrace deposits), volcanic loess, black soils, and Holocene dune sands in ascending order. In the basement rock, the main recession factors in winter are not only erosion by storm waves, but also exfoliation of the bedrock due to freezing and thawing, and collapse of the convexity during the non-winter season formed by the exfoliation. The marine terrace deposits above the bedrock have experienced small-scale failures in unstable areas due to erosion of the basement rock, and the dune deposits have experienced small-scale arc-shaped landslides. These erosions are partially progressing at a rate of 1 m/year.

In this sea cliff, a buried wave-cut platform formed in the mid-Holocene sea-level highstand is exposed, with a shoreline angle of 3.5 m in elevation. Furthermore, there are two levels of wave-cut platforms that undergoing formation, with the higher level (elevation 2 m) having no sediments, and the lower level one covered by sand and gravel in winter, showing a shoreline angle of 0.7 m elevation. The buried wave-cut platform is covered by a marine sand and gravel layer, which is presumed to be similar to that found at the low level described above. The relative heights of the two shoreline angles suggest that the relative sea level in the study area at the Mid-Holocene sea-level highstand was about 2.8 m higher than present.

The impact of sea level rise on the development of the southern Tiber delta and Ostia lagoon as deduced from a Mid- to Late Holocene pollen record

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A pollen record for a very precisely dated Mid- to Late Holocene lagoonal sequence from the former Ostia lagoon, in the southern extension of the Tiber delta in central Italy, demonstrates changes in local and regional vegetation. Combining these with results from other studies on environmental proxies (molluscs, foraminifers, ostracods), the record could be linked to changes in sedimentary facies in the lagoon. The sequence is from a tectonically stable area, with a subsoil that is not affected by Holocene subsidence due to sediment compaction, in contrast to the central and northern part of this delta, which is known for its massive subsidence. The changes in facies were used to reconstruct the sea level record for the Mid and Late Holocene and are compared to the existing curves for sea level change in this part of Central Tyrrhenian Italy. The record additionally allowed for a study of the potential impact of contemporary land use (notably salt production) on this environment.

Seamless marine and terrestrial topographic mapping from the seafloor to the intertidal zone and mountain slopes

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Red soil run-off caused by agricultural and other land development is causing problems with the Ramsar Convention-listed wetlands and coastal coral reef environment. This problem is also occurring in Nagura Bay, Ishigaki Island, Japan, where submerged karst landforms and large living coral communities are found, and efforts are being sought to protect the environment. In order to visualise and monitoring these marine and terrestrial issues, topographic maps connecting land and seafloor are needed.

We produced high-resolution Digital Elevation Model (DEM) for an area of 58.2 square kilometers including the Nagura Bay of 5 kilometers in diameter and its surrounding tidal flats, sandbars, rivers and mountain slopes, by combining the results of bathymetric survey using the Multibeam Echo Sounder (MBES) and the Airborne LIDAR Bathymetry (ALB) survey from shallow water to terrestrial area.

Multibeam bathymetric surveys were conducted using Sonic 2022 (R2 Sonic, LLC) in a rectangular area spanning 1.85 × 2.7 km in the central part of Nagura Bay and a 1 m grid DEM was produced. ALB survey was conducted with Chiroptera II (Leica Geosystems Inc.) and a 2 m grid DEM was produced. The maximum depths of ALB bathymetry were 15 to 20 m at the bay head, ~30 m at the middle of the bay and ~40 m at the bay mouth. The depth of ALB bathymetry increases as seawater transparency increases. The accuracy of the ALB bathymetry was verified comparing with 135,065 MBES data points obtained at the same location, which showed very good agreement (r = 0.997).

Seamless land-sea topographic maps, such as the one produced in this study, will provide important basic information for understanding environmental change in coastal areas in the Anthropocene and for developing future environmental management plans.

Contemporary pollution of surface sediments from the Algarve shelf, Portugal

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The present-day human footprint is traceable in all environments. Growing urban centers, tourism, agricultural and industrial activities in combination with fishery, aquacultures and intense naval traffic, result in a large output of pollutants onto coastal regions. The Algarve shelf (Portugal) is one exemplary highly affected coastal system. With this study the contemporary pollution was followed in eighteen offshore surface sediment samples.

Heavy metals (e.g., Cr, Pb, Cu, Hg) and organic contaminants, such as linear alkylbenzenes (LABs), dichlorodiphenyltrichloroethane metabolites (DDTs), polycyclic aromatic hydrocarbons (PAHs), and hopanes, have been identified and quantified, that pose hazardous effects on the marine environment and biota. This study correlates spatial distribution patterns with the pollutant composition, potential sources and pathways, each sample’s grain size, and local influences, such as discharging river systems and ocean currents.

Geoaccumulation of pollutants in the Algarve shelf surface sediments, controlled by sediment characteristics (grain size) and content of organic matter, threats marine environments. With considerable pollution, toxicity in marine environment is passed on into the food-chain through bioaccumulation posing long-term hazards for the marine ecosystem, aquacultures and fishery, and especially in the marine nature reserves.

This study presents a blueprint-study that allows the methodological adaption to new shelf systems with regionally different ocean current-driven distribution patterns of anthropogenic pollutants.

Risk assessment of land subsidence above sea cliff in Yonaguni Island, Japan

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Sea cliffs are formed by wave-induced erosion and collapses, around which there is an increase use as buildings or roads. Although the disaster risk caused by cliff recession is widely recognized, the hazard of land subsidence above sea caves is less recognized. The aim of this study was to assess the risk of land subsidence above the sea cave by 3D surveying from the ground surface to the inside of the caves and analyzing the relationship between the two.
For the data acquisition, a RTK-UAV (DJI Phantom4 RTK) and multiple action cameras (GoPro Hero8) were used on the ground and in the caves, respectively. Accurate 3D models and very high spatial resolution DSMs (1~5 cm/pixel) were generated by data processing on the photogrammetry software Agisoft Metashape Professional. The study area is located in the south coast on Yonaguni Island, Japan. The sector around the two surveyed sea caves is mainly made up of Pleistocene limestone. The larger cave is 81m long and up to 62m wide, and the maximum elevation of dome-shaped ceiling is 27.5m. This study revealed that this cave extends under the road located about 50m inland from the cliff edge. The ceiling collapse occurred most commonly below the road and the difference in height between the ceiling and the road is 13.9m. The thickness of the boulders deposited on the cave floor was up to 5.3m. In addition, there were few continuous joints from the cave ceiling to the ground on the 3D model. Based on these findings, the next collapse is unlikely to cause the road to subsidence because the cave roof is thicker than a single collapse estimated from the boulder size broken down in the past. However, the future risk of subsidence could increase due to the expansion of the joints or destabilization accompanied by a single collapse.
Therefore, analyzing a 3D model from the surface to the cave allows us to assess the risk of land subsidence and conduct the follow-up research, such as investigation of cracks on the road above the cave and confirming the collapse of the cave ceiling.

The role of hyperpycnal flows on the burial of plastic in prodelta deposits: the case of the Gulf of Patti (Tyrrhenian Sea)

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Plastic contamination of seas is a global problem of growing concern, at present affecting every environmental compartment of all oceans from coastal surface waters to the water column and the seafloor. Despite the seafloor is recognized as the main accumulation area for anthropic debris and the sequestration of plastic within sediments is considered the ultimate long-term sink of this pollutant, the physical controls on its distribution and burial remain poorly known. In this work, we document the presence of deeply buried macroplastics in prodelta deposits at the mouth of the Mazzarrà River, a steep mountainous river flowing into the Tyrrhenian Sea in the Gulf of Patti (NE Sicily). This torrential river is able to carry a large amount of sediment during seasonal flash floods, which are able to generate hyperpycnal flows at sea, as witnessed by the widespread occurrence of erosional and depositional bedforms over the prodelta deposit. These bedforms include cross-shelf gullies and “dune-like” seafloor undulations. Two macroplastic items, consisting of a fragment of a “pasta” packaging bag and a semi-circular piece of synthetic rubber, have been retrieved within a sediment core collected at 38 m depth within a prodelta channel aligned with the mouth of the river. Grain-size analysis on the cored sediment showed the occurrence of decimetre-thick sandy intervals with sparse gravel alternating with more silty-clayey intervals. The plastic items were found at 68 and 255 cm below the core top (corresponding to the seafloor), enclosed in the coarse-grained intervals and associated with terrestrial plant debris, suggesting that they were deposited through hyperpycnal flows triggered by flood events. The trapping and burial of plastics in nearshore and prodelta environments are favored by the efficiency of rivers as conveyer and transporting agents of litter combined with the high sedimentation rates during single flood events. These findings testify the efficiency of sedimentary flows in burying plastic at depth below the seafloor, highlighting a clear need for assessing the magnitude of plastic storage in a variety of depositional settings.

Microplastic transport and accumulation in the land-sea continuum: Multi-year sediment trap monitoring at an estuary of the Baltic Sea

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Microplastics are shown to accumulate in aquatic environment posing ecological risks. Majority of the microplastics in the oceans are derived from land resulting from traffic, industry and insufficient waste management. Yet, the flux rates of microplastics from catchments to water bodies are poorly investigated. Estuaries are shown to efficiently trap nutrients and organic carbon through various processes involving flocculation and aggregation. Previously published laboratory experiments have shown that these processes can influence microplastic accumulation as well. Hence, estuaries have potential to act as microplastic filters decreasing their access from coastal areas to oceans. However, the estuaries are vulnerable key ecological environments suffering from multiple environmental problems, such as eutrophication and deoxygenation. In order to understand and predict the added environmental risk posed by microplastics in these sensitive systems, it is crucial to understand the flux rates and processes controlling microplastic accumulation in estuarine systems. Here we report first results from multi-year sediment trap campaign, where microplastic accumulation rates are investigated together with sediment composition (detrital supply, organic C, trace metals, and phosphorus loading) and seasonal hydroclimatic conditions. Large seasonal changes in the boreal estuary of Halikonlahti in the Finnish southwestern coast result strong climatic control on sediment supply, sources, accumulation rates, and sediment composition. While majority of microplastic particles were PE and PP, which are most commonly found materials in the sedimentary archives across the world, the microplastic fluxes show significant temporal and spatial variation.

Groundwater discharge and tidal flushing dynamics related to modern microbialite systems on a drought prone rocky coast

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Extant microbialite systems precipitating in a hydrological environment formed by constant, fresh groundwater discharge and periodic marine water intrusion are known from global locations including Western Australia, the United Kingdom and South Africa. In semi-arid South Africa, these occur in the supratidal zone of rocky coasts and are especially numerous and well-developed in the Nelson Mandela Bay (NMB). Microbialites are layered organosedimentary deposits which form part of the longest uninterrupted geological record of life on Earth (3.4 bya). The layering of sediment and carbonates of modern microbialites potentially provides a window into historical environmental conditions. Rapid groundwater development in response to a severe regional drought has led to the exploration of the coastal aquifers on which the microbialite systems rely for groundwater inflow. This study provides insight into the current state of the coastal aquifers of NMB through the quantification of groundwater discharge via microbialite systems in terms of flow rate and volume. This is paired with *in situ* hourly microbialite pool water temperature and conductivity data to determine the effect of tidal flushing dynamics coupled to rainfall. Results indicate that in excess of 3.8 ML/d of groundwater is discharged to the NMB coast, with 78% of discharge points (xx per km) supporting active microbialite growth. Preliminary results suggest a seasonal variation in flow rate and tidal dynamics. This is the first spatial analysis of groundwater discharge volumes along the NMB coast and is especially timeous given the trend for groundwater development in the face of urban expansion and climate change linked to rising sea-level or storm surge prevalence and consequent increased saltwater intrusion into these microbialite pools.

Assessing tsunami susceptibility along the coasts of the Thermaikos Gulf, Northern Greece

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The study investigates the tsunami susceptibility along the coastline of the Thermaikos Gulf. For this purpose, a series of simulations were conducted by manipulating the Community Model Interface for the Tsunami (ComMIT) software. Several offshore seismic faults of the North Aegean Sea were taken into consideration as potential tsunamigenic sources. The parameters of the focal mechanism of past seismic events that may trigger tsunamis were retrieved from earthquake catalogues. The results of the simulations revealed that tsunamis, triggered by submarine earthquakes, can cause an extended inundation in the coastal area of Thermaikos Gulf. In order to validate our results, detailed geomorphological mapping was conducted and two shallow boreholes were drilled at Alykes lagoon (western coast of the Thermaikos Gulf) in an attempt to recognize the late Holocene palaeoenvironmental changes. In total, 64 sediment samples collected from the cores, were granulometrically and palaeontologically analysed. Moreover, two shell samples were ^{14}C dated and provided the chronostratigraphy of the cores. Four biosedimentary units were identified corresponding to different depositional palaeoenvironments. A shallowing upwards sedimentary sequence was recorded indicating a shallow marine environment which progressively changed to a more protected lagoonal one, with restricted communication to the open sea. The fining upwards sequence of the sedimentary record of the cores was interrupted by a coarse-grained layer corresponding to a high energy marine inundation event attributed most likely to a palaeotsunami which occurred not long before 4330–3920 cal BP. A similar strong marine signal which is regarded as a sedimentary feature indicative of a tsunamite has been documented by other studies in the same region as well as at Cape Epanomi and Sozopoli at the eastern coast of the Gulf. This signal correlates well with the high energy marine inundation layer documented in our study validating the simulation results. Our study can provide decision makers with important information for land-use planning, determining safe and unsafe areas for urban development along the coasts of the Thermaikos Gulf.

Earthquake history of Northern Cyprus, implications from coastal geomorphology and geochronology

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Cyprus is an island located on a convergent plate boundary in the Eastern Mediterranean. The African Plate subducts and collides with Anatolian Plate along the Cyprus Arc. The distance between northern Cyprus's coasts and the plate boundary varies between 70 km and 3 km from west to east. Nevertheless, the offshore escarpment of northern Cyprus is delimited by a dip-slip fault with a strike-slip component. However, the seismicity during the instrumental period is very low along the northern shore. Our high-resolution geomorphic mapping of coseismically uplifted landforms and biological and archaeological markers (fish tank) reveal that the northern coast of the island was hit by several earthquakes nucleated by offshore faults capable of producing enough seismic energy to deform the shoreline. The radiocarbon 14C ages of the biological marker (algal rims etc.) reveal that the coseismic uplift of the shoreline starts from 4 ka to 1.2 ka BP. The number of paleo shorelines is three at some sites, and their elevations rise to 3 m above sea level, indicating multiple earthquakes along the same segments of the offshore faults. The spatial distribution of radiocarbon 14C ages displays that the ages are getting younger toward the east, which might indicate the migration of stress toward the east.

Quaternary Flexure and breaking of the African Plate along the Eastern Mediterranean Coasts: implications from deformed marine terraces

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The African, Aegean and Anatolian plates converge in the Eastern Mediterranean Sea. The African Plate subducts beneath the Aegean and Anatolian plates along the Hellenic and Cyprus arcs, respectively. This subduction gives rise to the down-riding of the oceanic lithosphere under the Agean and Anatolian plates and the flexure of the African Plate. The coasts of eastern Libya (Cyrenaica) and western Egypt are among the best places to observe ongoing deformation on a down-riding plate in a subduction zone. Nevertheless, most of the efforts have focussed on the northern and eastern coast of the Eastern Mediterranean Region. Today, the southern coasts are low-strain regions, and the number of large-magnitude earthquakes is limited during the instrumental period. However, the coastal geomorphology reveals the presence of several uplifted marine terraces stretching hundreds of kilometres between Sirte Bay (Libya) and the Nile Delta, implying young deformation. Geomorphic mapping and morphometric analysis indicate that the shorelines of marine terraces are strongly deformed. The elevation of the same shorelines dramatically increases the along the strike of the shore. Their spatial distribution and geometries resemble a folding and, thus, flexing of the African Crust. The Marmarica Basin is located between deformed marine terrace regions and is characterised by several east-west striking en-echelon normal faults. They are the surface expression of the breaking of the flexured crust response to the down-riding of the African Plate. All these geomorphic markers reveal that the northern coast of Africa is strongly deformed in Quaternary and should be reassessed in terms of seismic hazard.

A new landslide inventory map in the Southern Swiss Alps

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Landslides in urbanized mountain environments often threaten the infrastructures and population settled near the slopes. In this context, detailed knowledge of the types of gravitational phenomena, their extension, and state of activity is fundamental for risk reduction. In this study, we revise the current landslide inventory map of Canton Ticino (Ambrosi and Czerski, 2016) and present a first landslide inventory of the Moesa Region of Canton Graubünden, Switzerland. This inventory consists of a mapping of the landslides classified according to Varnes (1978) and Hungr et al. (2014), which include phenomena as falls, flows, slides, and Deep Seated Gravitational Slope Deformation, DSGSD. In addition, we complemented the map with morpho-structures.

Mapping was carried out by interpreting hillshade views generated from high resolution digital terrain models, historical aerial photos, and images from aerial strips visualized by stereo-photogrammetric technology. An evaluation of the state of activity of the landslides was performed using the available data from geodetic monitoring and Interferometric Synthetic Aperture Radar (InSAR) through Permanent Scatterers (PS) and Interferometric Point Target Analysis (IPTA) techniques. The available InSAR data include the Sentinel-1 mission from 2014 to 2021, TerraSAR-X from 2014 to 2019, and RadarSAT from 2011 to 2018. The sensor of each satellite utilizes different acquisition parameters, thus can reveal the surface displacements with different accuracies, depending on the slope displacement magnitude, presence of vegetation, and slope orientation. The results of the mapping were statistically analyzed in relation to the relief topography, in order to understand the tendency of different morphological environments to favor or disfavor specific gravitational phenomena.

The new inventory provides a tool for local government to update hazard zoning, allowing them to limit construction, plan necessary technical protection measures, and manage emergencies in case of major events.

Geomorphological classification and hazard mapping considering both natural and anthropogenic landforms in Japan

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In this decade, a series of heavy rainfall events have led to frequent flood and sediment (e.g., slope failures, landslides, and debris flows) disasters in the Japanese archipelago, among them events in Hiroshima (2014), Kanto and Tohoku (2015), Northern Kyushu (2017), Western Japan (2018), Eastern Japan (2019 Typhoon), Kumamoto (2020), and Atami (2021), that have killed dozens of people every year. Over 10,000 slope failures and dozens of riverbank breaches have abruptly changed landforms, for example, by deepening upland valleys, forming alluvial cones and crevasse splays, changing river channels from meandering to braided, and shortening the courses of rivers. Concentrations of such sudden changes occur in geomorphic hot spots, sites where high volumes of water or sediment make short-term sedimentation or erosion events more likely. Photogrammetry conducted with unmanned aerial vehicles coupled with grain size and geochemical analyses of event sediments and 14C dating has revealed that geomorphic hot spots can be divided into two types: natural and anthropogenic. Natural hot spots are located at node points of sediment routing such as valley heads, river junctions, fan apexes, and avulsions; at such sites flooding and sediment events have occurred repeatedly during the Holocene. Anthropogenic hot spots are located where artificial landforms have been created, such as valley fills, terraces constructed on steep hillslopes for agriculture, and river channels modified by the elimination of meanders, the lowering of banks by removing dunes or not raising levees in low-lying areas, or the narrowing of channel cross sections by bridging or tree growth. Such local anthropogenic topographic changes may also trigger the regional geomorphic system to transition to a new equilibrium state. To reduce vulnerability to sediment and flood disasters in tectonically active and intensely denuded regions with a high population density such as Japan, it is crucial to distinguish between natural and anthropogenic geomorphic hot spots. Hazard maps should be based on a detailed geomorphological classification system that reflects both naturally developed Quaternary landforms and artificial landforms.

Geological and geomorphological features of landslides by August 2021 heavy rainfall at the foot of Mt. Mutsu-Hiuchidake, northern Honshu Island, Japan

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Volcano-alluvial fans are comprised of unconsolidated material and steep faces can be created by erosion, forming favorable conditions for landslides. We investigated the geological and geomorphological features of landslides induced by heavy rainfall on 10 August 2021 along the coastal area at the foot of Mt. Mutsu-Hiuchidake, northern Honshu Island, Japan. The area received the maximum hourly rainfall intensity of 59 mm hr^{-1} and the cumulative rainfall in two days of 385 mm, which was about 2.6 times larger than the average rainfall in August in this area, resulting in one of the most major prefectural natural disasters of recent years. The bedrock in the study area is Miocene-Pliocene to Pleistocene in age and comprises, in ascending order, Ohata formation (pumiceous tuff, tuff-breccia, sandstone, and mudstone with basal conglomerate) and volcanic products of tuff-breccia. Field surveys showed that the fan surfaces mostly gentler than 15 degrees are distributed at about 50 m a.s.l and are surrounded by steeper slopes (of about 40 degrees) with well-defined slope breaks whereas old landslide scarps can be observed in many locations. Landslides by this rainfall event were mainly distributed on the steep slopes, along the slope breaks, and above the old landslide scarps. Besides, outcrops exposed by landslides suggested the bedrock is overlain by volcano-alluvial fan deposits of 3-10 m thick consist of matrix or clast-supported massive diamicton with muddy or sandy matrix and matrix-supported bedded diamicton with altered materials. Landslides occurred associated with the above materials generally had piping holes within the tops of the landslide scars, suggesting the locations of these landslides must be controlled by the concentration of groundwater in the volcano-alluvial fans.

Sediment sources and discharge as disaster and environmental risks in an upstream mountainous catchment in northwestern Vietnam

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The northwestern region of Vietnam, the most mountainous area in the country, has suffered from frequent occurrence of mountain disasters caused by landslides, debris flows and river floods. The area has also long faced catchment-scale active sediment movement which involves various hillslope processes likely affected by land-uses. Our study aims at investigating important sources and processes of sediment movement and quantifying sediment discharge at a catchment-scale, in order to contribute to assessment of disaster and environmental risks in mainland Southeast Asia, where such risks have not yet been well documented.

Our study catchment, c.a. 200 km^2 in area and located in Yen Bai Province, northwestern Vietnam, is largely underlain by rhyolitic volcanic rocks and tuff, often intervened by shales. The catchment is at altitudes between approximately 900 m and 2000 m a.s.l. Deforested and terraced agricultural fields are extensively distributed on footslopes and middle slopes, while they are not observed on the slopes where soil layers are thin. Forest types vary, but extensively include highly degraded forest composed of regenerated shrubs and bush.

During the field survey in the 2022 rainy season, river water of the main stream of the catchment appeared highly turbid during a rainfall event; however, tributary river water was not equally turbid even though water levels looked higher than base flow, suggesting specific areas in the catchment were more contributing as sediment sources. A series of water samples collected through the sampling campaign along the main stream in a rainy-day, together with land-use and landform analysis using satellite images, revealed that erosion was occurring most distinctively in areas where artificial landform transformation took place. Infiltration tests on land surfaces under forest and degraded forest showed almost the same infiltration capacity, suggesting surface erosion would not be always critically accelerated by deforestation. However, the spatial distribution of landslides in the study area suggests deforestation likely increases the risk of shallow landslide, and former landslides (i.e. soils decomposed by landslides) were a major source of sediment in some of the tributary areas where highly concentrated suspended sediment flowed.

Mapping the subsidence susceptibility of the Ebro Delta from geological information

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Modern river delta plains in general are areas very susceptible to flooding because of their low elevation. This is the case of the Ebro Delta plain (northwest Mediterranean coast, 320 km^2), where more than 40% of its area is less than 50 cm above sea level. Aside from the sea level rising, the flooding hazard of delta plains can also increase because of subsidence (the absolute lowering of the ground surface elevation). In this context, we have developed a zonation of subsidence susceptibility on the Ebro Delta plain based on the analysis of the different relevant geological factors that influence it. To achieve it, firstly, a detailed geological characterization of the Holocene prism of the Ebro Delta has been carried out based on the compilation and analysis of new and pre-existing data.

The subsidence associated with natural mechanical compaction of Holocene delta deposits, has been estimated based on their 3D sedimentary architecture and their geomechanical properties. On the other hand, it was analyzed the contribution on subsidence of the flexure of the lithosphere related to the deposition of water and sediment in the Ebro margin since the Last Glacial Maximum, and the regional tilting of the Ebro shelf during the Quaternary. The subsidence estimates associated with these three factors are broadly coherent with the DInSAR subsidence measurements. In addition, other minor factors and features able to locally modify the Ebro Delta plain subsidence (e.g., recent sedimentary dynamics, the chemical and biological compaction of sediment, or the effects related to anthropogenic activities) were also qualitatively evaluated. The joint analysis of the different information sources allowed the composition of a subsidence susceptibility map, which indicates that the subsidence in the Ebro Delta plain ranges from <1 mm/year (in the inner delta plain) up to ~2.3 mm/year (in some parts of the outer delta plain). This methodology, fundamentally based on geological information and knowledge, is being implemented in the other main coastal plains of Catalonia to predict the subsidence distribution and to facilitate the management of these vulnerable areas.

Geostatistical approach of submarine landslides: new insights on mass wasting dynamics along the Italian continental margins

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Submarine landslides are usually very large events respect their terrestrial counterparts, are an important process for sediment transfer, can generate tsunamis and therefore represent a very relevant geohazard for marine and coastal infrastructures. They are globally reported along both active and passive margins and are often associated with specific submarine morphologies (e.g., canyons, pockmarks, seamounts).

Despite their frequency and relevance, submarine landslides are far harder to monitor and study than terrestrial landslides, and much greater uncertainty affects their preconditioning factors and triggers, and this has led to a huge disparity of knowledge between mass wasting in the two different environments and therefore a large uncertainty for geohazard assessment exists in the marine realm.

Marine observatories and long-term studies on marine landslide are very few as in situ measurements and monitoring are technologically challenging and economically demanding. On the other hand, in the last decades, the availability of very high-resolution sonar data (up to centimetres) allowed to observe morphologies never observed before, bringing new insight on their dynamics

The Italian continental margins provide an excellent playfield to study submarine mass wasting because of their different morpho-tectonic and sedimentary setting. Between the 2007 and 2013, a detailed regional mapping program of seafloor morphologies and features including mass wasting were funded by the Civil Protection (DPC) through the MaGIC project that gathered seven universities, three institutes of the National Research Council and the National Institute for Oceanography and Applied Geophysics (OGS), with the objective of providing the DPC with occurrence and distribution of geohazard-related features including submarine mass wasting and associated deposits.

In the framework of the PNNR Project GEOSCIENCES IR we propose to integrate all the existing data along the continental margins, indicative of mass wasting in a new well-constrained geodatabase. Such platform will allow to apply statistical methods to constrain better mass wasting dynamics in relation to different geological setting and to recognise the role played by predisposing and triggering factors.

Preliminary results on geomorphic and seismological analysis on earthquake and tsunami hazards in the inner Northern Apennines

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The inner Northern Apennines are considered as a region of only moderate to low seismic hazard, however recent findings suggest that the faults of the region might display a much greater threat than previously thought. Indeed, the faults might be able to cause not only larger (M>5-6) magnitude earthquakes but also tsunamis. Of our special interest is the 1846 ~M6 Orciano Pisano earthquake which caused major destructions at the time and, based on historic reports, is also suspected to have caused a tsunami. Despite the effects this event had on the region the location and source of the earthquake is still unknown and hence its seismological relevance remains unclear. Clarifying these issues is crucial as a similar event today would likely have devastating effects on the densely populated area.

So far, a new geomorphic analysis shows some indications of recent tectonic activity for the faults of the region whereas their large-scale architectural frame need to be better understood. In particular questions remain whether the N-S fault systems predominately recorded in the area are the only active systems, and what is the role of the E-W trending systems. To better understand fault activity, the seismicity of the area recorded by the INGV earthquake catalogue since 1985 has been analysed. Initial analysis shows continuos seismic activity over the past ~30 years with events magnitude as high as M 4.0 and a depth distribution in the upper crust down to ~20 km. Furthermore, the data set shows several interesting clusters and patterns in the region indicating activity along both the N-S striking faults as well as on the E-W striking structures in the area. The INGV catalogue has hypocentral errors of several km's due to the location methods used and the relatively modest density of seismic stations. In order to image the subsurface active fault planes and their kinematics reprocessing and relocation of past earthquake clusters will be done. In addition, a new temporary seismic network of 8 stations has been set up to densify the network to accurately locate current and future earthquakes.

The listric faults bounding the Dor Disturbance from the southeast: indications for recent major seabed ruptures

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The thin-skinned faults crossed by the Leviathan gas pipeline, and bounding the Dor disturbance (offshore Israel) from the southeast are exceptional relative to other thin-skinned normal faults nearby. (1) Whereas most of the faults are aligned along the base of the continental slope, these faults are located on the upper slope. (2) Their dip angle is relatively small, beginning with about 45 degrees near the surface and gradually changing to 10 degrees at depth. (3) However, they stop above the base Pliocene and do not penetrate the top of the Messinian salt layer. (4) Their width is large relative to the faults developed above the salt wedge-out. (5) They produce large seabed scarps despite their location in a high sedimentation zone. In fact, the sedimentation rate at that location (~200 cm/ky) is four times larger than the displacement rate (~50 cm/ky), averaged at 350 ky. Allegedly, this observation indicates that either these faults creep faster than the sedimentation rate or they operate in rapid episodes or “slow earthquakes”. To better understand the formation of these listric faults and assess the hazard they pose, we performed a high-resolution, multi-channel, seismic reflection survey south of the Dor Disturbance. We map three unconformities on and off the shelf and date them using sequence stratigraphic principles and a global sea-level curve. Considering the dated seismic reflectors, we measure fault offsets and calculate the displacement rates throughout the history of the fault motion. Results show an acceleration of the moving during the last ~14 ky, with displacement rates of 2.5-3.5 m/ky. Also, the backward restoration shows quiet periods with no fault motion. In this talk, we will present the preliminary results and discuss their implications.

Reassessing fault activity over different time scales in the Lower Rhine Graben and the processes controlling scarp preservation, towards an improved fault database.

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The Lower Rhine Graben is an area of slow intraplate extension (~0.1 +/- 0.03mm/yr) in northwestern Europe. The major active faults are well known, but the structures presenting limited surface deformation or the detailed fault geometry are often overlooked, mostly because such slow deformation produces weak tectonic signal, easily overprinted by other processes. We present, for the entire region, a revised and homogeneous fault map, based on morphological observations of fault scarps and offset alluvial terraces realized on a high-resolution Lidar-based DEM, complemented by external information from paleoseismological and geophysical surveys. We compiled our active faults model in a database, including several levels of fault mapping (traces, fault sections, faults), with indications about the certainty of the faults identification and location.
The eastern side of the graben exhibits clear scarps and sharp boundaries, while the western side presents smoother cumulative scarps, suggesting contrasting fault behavior across the graben. Moreover, the number of faults increase drastically southward pointing to a N-S contrast in terms of graben development. This map also points to variations of scarp preservation along the graben that are not related only to the local geology. We observe many small structures that are surprisingly well-preserved compared to their assumed rates of activity and recent landscape remodeling processes (climate, anthropogenic…), raising the question of the role of the periglacial condition in scarp preservation.
To better understand the sources of these variations, we refine the assessment of the fault activity through time and along strike. In the southern part of the graben, a well-developed terrace has been used to estimate the activity of most faults over the Quaternary. In addition, we use several 3D-geological models to retrieve the vertical offsets, and obtain the spatial slip distribution at different timescales. We observe that, along individual faults, the slip profile evolves laterally and in time, showing fault linkage, while at the scale of the graben borders the total slip is relatively homogenous. Moreover, in the northern part, although the surface-expression differs between the two sides of the graben, the total slip rates are fairly equivalent on both sides, suggesting a symmetrical extension.

Could phreatomagmatic eruptions trigger reverse faulting? A paleoseismic history and stress modelling at Antarctica

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The relationships between earthquakes and volcanic eruptions have been studied as processes with the potential to trigger each other. Large earthquakes greater than M = 7 and subsequent significant eruptions can be related as a causative phenomenon in very active tectonic frames, such as subduction zones and mid-ocean ridges. Recently, large earthquakes activating stratovolcanoes have been described, although the underlying mechanisms are poorly constrained. However, no cases of volcanic and earthquake interactions have been described from volcanic eruptions triggering moderated-size earthquakes, this also showing geomorphological and paleoseismic evidence. In this work, we describe the paleoseismic record of reverse faulting triggered by a phreatomagmatic eruption in Deception Island (West Antarctica). A powerful phreatomagmatic eruption took place in the inner bay shoreline of the island in 1970, destroying the Chilean Antarctic Station and generating three WNW-ESE aligned craters, affecting an area of 380 x 184 meters. The analysis of aerial imagery before and after the eruption identifies an apparent E-W surface rupture with a reverse movement also revealed by paleoseismic trenches and geomorphic volcanic terraces. Moreover, we have studied the static stress changes induced by the phreatomagmatic eruption on the E-W fault, with the aim to connect paleoseismic observation, geomorphological analysis, and volcanic eruption. We propose three volcano-tectonic interactions models: (1) Reverse earthquake (5<M<6) triggered by the 1970‘s phreatomagmatic eruption; (2) Reactivation of a previous fault as a consequence of dike injection and/or magma migration in relationship with the eruptive process and (3) Aseismic fault creep activity post-volcanic eruption. Hence, this work represents a good opportunity for matching volcanic eruptions and earthquake faulting with surface rupture for opening a fruitful scientific discussion.

Interference among volcanism, faulting and Quaternary fluvial terraces in the Cabriel Valley (Valencia, East Spain).

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This work analyses the Quaternary volcanic activity within the Cabriel Valley in the northern end of the N-S trending Ayora-Cofrentes graben (Valencia East Spain). Normal faulting facilitated Quaternary volcanic activity from subcrustal levels, geochemically characterized as olivinic nephelinites (limburgites) with olivine-piroxene phenocrystals.

The study identifies three independent volcanic outcrops recording different eruptive events: Agrás Volcano (AGV); Pico del Fraile (PDF) and Cofrentes Castle (CFC). The AGV is a small strombolian cone, 50 m high with 450x325 m dimensions with two original elongated craters evidencing different overlapped edifices, close in time. Volcanic activity intrudes, disrupts and embeds the oldest terrace of the Cabriel River (+130-135 m). The basal pyroclastic levels show abundant cauliflower-shaped bombs, lapilli and chilled rim pyroclasts supporting the presence of water during magma rise (hydrovolcanism). Towards the top of the volcano interbedded basaltic levels (8m thick) become abundant, indicating eventual lava-flow activity. Subvertical basaltic dikes, N-S to NNW-SSE, trend with the regional fault system. Paleomagnetic determinations using a portable fluxgate magnetometer consistently indicated reverse polarity (Matuyama) according to published K/Ar dating (2.0 – 1.4 Ma).

At the base of the AGV, the PDF materials show normal polarity (Brunhes) and disrupt and overlap the +50 (ESR: 370 ka) and +40m (OSL: 180 ka) terraces of the Cabriel River. The remnants of the edifice outline a crescent-shaped rim opened to the SSW facing to CFC outcrop in the opposite side of the valley. The rim preserves massive pyroclastic and peperite materials, with abundant clastic components in a palagonite-like matrix indicating explosive phreatomagmatic activity. Resurgent activity records pseudo-pillow lavas above the +40m fluvial level which also embed peperites. This assemblage indicates subaqueous volcanic activity contemporaneous to the formation of the +40 m terrace during the Middle Pleistocene (MIS 7).

The CFC outcrop record a basal mélange (20m thick) of volcanic materials with large blocks of the Neogene and Triassic substratum, topped by a pyroclastic deposit containing pervasive small-rounded fluvial gravels. This last outcrop is interpreted as the remnants of pyroclastic flow coming from the PDF blast. Hydrothermal activity around the area suggest some type of latent activity. FUNDED BY MINCIN-FEDER 2021-123510OB-I00

Structural control of rapid magma ascent during Cumbre Vieja eruption (La Palma, 2021): the role of fault intersection in dyke ascent

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On 11 September, a tecto-volcanic earthquake cluster started underneath La Palma (Canary Islands). Eight days later, a strong strombolian eruption began in the Cumbre Vieja volcanic ridge, located in the southern part of the island. As a consequence, the new scoria cone born and it was in the ongoing erupting mode for 85 days, with alternating ash columns up to 8 km height. Besides, the eruption emitted lava fields with a total land covering of ca 1100 Ha, and a huge volume of tephra with fine ash which covered the entire island and affected ordinary aerial traffic.

A vast quantity of magma was emplaced at 11 km depth at the beginning of the volcanic unrest, 11/09/2021. Four days later magma moved shallower and was emplaced between 6 and 2 km depth. Finally, on September 19, the eruption began. The rapid dyke ascent, was controlled by a previous pre-existing fault trending NW-SE. Several volcanic vents trending NW-SE emerged whereas the magma was moving along the fault, from SE to NW. Moreover, the presence of another previous fault trending ENE-WSW was also affected by the magma rising, and controlled the opening of new vents during the final volcanic stages. In total, more than thirty vents were opened been the most active the scoria cone on the intersection between those two previous faults, NW-SE and ENE-WSW, main and secondary respectively. Relocation of earthquakes shows a dyke ascent from southeast to northwest, between 20 km and 5 km depth and an average dip of 65°S. We suggest that the dyke reaches the fault intersection and ascends rapidly in a vertical mode filling the normal fault plane (NW-SE), and opening vents along 1.2 km length. When the NW-SE fault plane was totally full of magma, its overpressure reactivate the ENE-WSW and the magma moved through it, opening new vents from ENE to WSW during the last 15 days of the eruption. Therefore, the structural control of previous Quaternary faults under an extensional tectonic regime takes control of the rapid magma ascent and the spatial distribution of the vents.

Morpho-structural analysis of the active volcanic Ischia caldera using drone-based LiDAR: a new method to improve the spatial resolution of DTMs

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Ischia Island is an active volcano in the northern sector of the Gulf of Naples, which belongs to the Neapolitan volcanic system (southern Italy). The island represents an interesting case study of long-term resurgence and subsidence processes in active volcanic calderas. The final stage of the resurgence phase formed Mt. Epomeo (787 m elevation), the main morphological structure emerging nowadays, and bounded by NW-SE, E-W, and N-S normal faults. Early studies associated seismic activity with the E-W faulting system north of Mt. Epomeo. This is in fact the epicentral area of the July 28, 1883, earthquake, which completely destroyed Casamicciola Terme and caused ~2300 victims. The last moderate earthquake (M_d=4.0) occurred in the same epicentral area on August 21, 2017. Although much has been done so far, understanding the fault geometry and kinematics here is still debated. These are volcanotectonic seismic events with a very shallow hypocentral depth (1-2 km) and moderate-to-low magnitude (3<Mw<5). However, owing to extremely high exposure and vulnerability, the associated risk is very severe.

Analysis of the surface expression of volcanotectonic deformation allowed us to identify and constrain the structural architecture of this active volcanic and seismic area. Thus, we carried out a morpho-structural analysis (e.g.,lineaments, fault scarps, and slope maps) interpreted from shaded relief images processed from digital terrain models (DTMs) at 10 cm resolution. For obtaining accurate bare-earth elevation data and enhance its acquisition, we used a LiDAR sensor transported by the DJI-Matrice-600 drone. The drone-Lidar survey covered an area of 2.2 km^2 between Grande Sentinella horst and a normal master fault at the base of Mt. Epomeo. This tool represents the most advanced remote sensing technique for generating high-resolution digital elevation models.

In this study we present both the workflow and the methodological computing technique followed to generate the most precise high-resolution DTMs, removing the presence of vegetation and buildings. This technology showed a high potential for quantifying the deformation rate of the area by constraining the volcano-tectonic model. The results will be crucial for evaluating the dynamics of seismogenic structures in the framework of the proposed resurgence and subsidence activity in Ischia.

Travertine deposition and fissure ridge development in the geothermal field of Viterbo (Northern Latium, Italy)

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Several thermal springs (52°C to 65°C) of sulphate-alkaline-earthy waters, used since Roman times, occur west of Viterbo (Latium, Italy) in an area of the large volcanic plateau covered by extensive travertine deposits. This area, with high heat-flow values (200-300 mW/m^2 up to 450 mW/m^2), corresponds to a buried structural high, mainly identified through geophysical data. It corresponds to a Plio-Quaternary horst in which early Miocene thrust and folds related to the Northern Apennine's tectonic evolution and affecting the Tuscan Units are preserved. The substrate of the travertine carbonates consists of a pyroclastic succession derived from three volcanic districts (Cimino, Vico and Volsini, active between 1,35 Ma e 90 ka), which buried the Tuscan Units. The thermal springs are located along the traces of the main oblique-slip and normal faults. Travertine bodies developed and are still developing around them, both for chemical or biological processes, forming shield/crater mounds (Piscine Carletti, Bullicame, Bagnaccio), mushroom-like domes (Paliano) and fissure ridge (Bacucco, Aeroporto, Asinello). The related distal thermal drainage system is characterized by carbonate bodies made of dominant microbial laminites, typical of swamps/palustrine environments and/or shallow lakes filled with mixed thermal and ambient water. Fissure ridges are built up by thin, subvertical crystalline crusts forming two symmetric laminated bodies separated by a longitudinal open fissure, locally filled by banded, onyx-like crystalline carbonate (aragonite and/or calcite). The feature of the flanks of the ridges reflects a sheet of water flowing on the flanks of the slope with laminar or turbulent flux and welling up from an open fracture now dried up for most of its length. The travertine deposition was and is still controlled by the combined effects of different leading processes reconciled in a geothermal setting with continuous tectonic activity.

The youngest Quaternary tectonic crustal stresses in the Bohemian Massif inferred from the faulted lava flow of Komorní Hůrka Volcano (1.1 Ma) (Czech Republic)

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In order to expand the range of knowledge about the youngest Quaternary tectonic stresses that acted in the Bohemian Massif, the brittle deformation of the lava flow of one of its youngest volcano Komorní Hůrka (0.7 - 1.01 Ma) was studied. Komorní Hůrka Volcano is situated in the Cenozoic seismoactive Cheb basin in Western Bohemia (Czech Republic), which is famous by Pleistocene volcanism, mantle-derived CO_2 emanation and present day, probably fluid-driven earthquake swarms.

Within the observations and measurements on the lava flow, we have identified several generations of striations differing in their morphology, which were successively formed and superimposed one over the other during the last ca. 1 Ma. The measured heterogeneous set of fault slip data was separated into homogeneous sub-sets using an automatic procedure completed by a technique based on recording mutual superposition of striation populations. Both optical microscopy and SEM were used to estimate the original conditions of the individual populations of striations.

Three generations of striations were recognized. The oldest generation of striations (represented by two similar homogeneous sub-sets) were analyzed by optical and SEM microscopes, which revealed their abnormally plastic morphology as well as reduced content of Na, K, and increased content of SiO_2 in the outermost layer of slickensides. This implies that these slickensides were formed during high temperatures, which we interpret as a record of mutual collision of the semi-solidified blocks of the lava flow during the effusion process.

The younger generation of striations was produced in already solidified (hard) rocks by tectonic stress with parameters very close to the present crustal stress as identified from earthquake focal mechanisms in Western Bohemia.

The youngest homogeneous sub-set was reactivated by vertically oriented, nearly uniaxial compression. Due to the low number of assigned/analyzed fault-slip data, we only hypothesize it might be an indication of the action of pressurized fluids. This would imply for example possible dyke emplacement, which might have had also a causal relationship to documented large late Quaternary surface-rupturing earthquakes in the Cheb basin.

Active and capable faults (ACF) at Mt. Etna volcano (Italy): the contribution of field geologists for seismic microzonation analyses and territorial planning

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Field evidence of active tectonics at Mt. Etna volcano (Italy) is a widespread and well-known feature since the mid-1800s. Here faults display two end-member modes of rupture mechanism, with different sections of the same fault governed by stick-slip (earthquake-related slip) or stable-sliding behaviour (aseismic creep). While coseismic displacements due to shallow small-size earthquakes (M < 5, depth < 2-3 km) can be impressive (max vertical offsets 90 cm, max strike-slip 50 cm), with end-to-end ruptures up to 8 km, near-continuous ground fracturing produced by fault creep is responsible for significant cumulative displacements in the long-term. Field observations indicate that both phenomena affect mainly the eastern flank of Etna (faults of the “Timpe” system) but also other sectors of the volcano host, although at a lesser extent, not negligible fault slips. Mapping distribution and characteristics of surface faulting in areas lacking of morphotectonic features, has also permitted to recognize hidden faults, i.e. surface breaking faults that do not exhibit a clear and permanent associated geomorphology. These concealed structures, buried by Holocene and historical lava flows, are not isolated but represent discrete segments of major, continuous fault zones. While from a purely scientific viewpoint, studies on surface faulting made possible to constrain seismotectonic models, to produce active fault maps as well as to understand local geodynamics, the impact of the effects produced by capable faults on local communities living on the urbanized flanks of the volcano, is still little investigated. To this end, the Department of Civil Protection of Sicily engaged the “Centro per la Microzonazione Sismica” (constituted by CNR and other research institutions and universities) for a project aimed at preventing and reducing seismic risk in the frame of the regional plan for seismic microzonation (26 municipalities in the Etna region). Here it is presented the task devoted to the characterization of the active and capable faults (ACF); the main activity steps are: 1) collection of literature data on ACF; 2) population of a GIS platform; 3) definition of study areas for geophysical/geotechnical surveys; 4) ACF guidelines for volcanic zones in the perspective of risk mitigation planning for the urban areas.

Surface ruptures accompanying the 2021 Cumbre Vieja volcanic eruption (La Palma, Canary Islands) and their possible relation with an early-stage flank instability

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Flank instability is an important issue related to many volcanoes because it can lead to catastrophic flank collapses. The Cumbre Vieja 2021 volcanic eruption, started in September 2021, represents a significant event in the study the links between magmatic, volcano-tectonic, and gravitational processes. Between 25th November and 5th December 2021, during the final phase of the eruption, a complex network of fissures affected the NW flank of the volcano, with an "unexpected" trend almost perpendicular to the volcanic slope and to the coastline. Surface ruptures started at the southeastern edge of the main eruptive fissure. In July-August 2022 we mapped the ground ruptures affecting mostly buildings, paved roads but also the 2021 lava flow and volcanic fall-out deposit. We collected structural data along 63 surface ruptures observing mostly pure dilational with minor strike-slip components. The fractures strike is 275° on average with a WNW-ESE trend. We also observed hot gas emissions from some of the eastern ruptures closest to the lowest and late eruptive fissures. From the field observations analysis, it is possible to hypothesize the occurrence of an early-stage instability in the western flank of the Cumbre Vieja volcanic system with a slow sliding toward the sea. Dilational stresses along the instability zone can promote magmatic intrusions as demonstrated by the several eruptive vents aligned along the western flank of the Cumbre Vieja (NW-SE and WSW-ENE). A similar behavior has already been observed during the 1949 eruption where a NNW-SSE fault rupture occurred on the Cumbre Vieja western slope. We infer that the 2021 eruptive fissures and the surface ruptures could be the extension of the 1949 fault system with a propagation of the instability to the NW, that is toward the coastline. After the eruption, no reactivation of these fractures was observed, suggesting that the edifice is not close to collapse, but also the need of ground deformation monitoring. These results can lead to a better volcanic hazard assessment in La Palma Island and also promote in-depth studies on the possibility of flank collapse.

Reconstructing Holocene palaeoenvironmental conditions in the Egyptian Nile Valley using soil rhizoliths

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Recent morphosedimentary analysis in the Nile Valley at Luxor (Upper Egypt) shows major changes in River Nile behaviour in response to Holocene climate change. What is more, these large-scale alterations to the fluvial system may have influenced patterns of human activity on the Nile floodplain since the Egyptian Middle Kingdom.

However, palaeoclimate archives from this region are currently scarce, hindering more detailed reconstructions of past environmental change. Importantly, the Luxor alluvium is abundant in rhizoliths; secondary carbonates that form around plant roots. Their microstructures and stable isotopic composition capture environmental conditions at the time of formation, such as aridity and vegetation type. While secondary carbonates, including rhizoliths, have been widely used for arid zone palaeoenvironmental reconstruction elsewhere, their micromorphology has not yet been examined in detail in the Egyptian Nile Valley.

Sediment cores collected across the Luxor floodplain as part of the Theban Harbours and Waterscapes Survey (THaWS) are rich in rhizoliths. Borehole age-depth models are constrained by Optically Stimulated Luminescence (OSL) dates and archaeological analysis of ceramic-rich horizons, yielding basal ages of ~4 ka. These borehole records thus provide an unrivalled opportunity to examine River Nile activity and floodplain conditions in relatively high temporal resolution and in close stratigraphic association with archaeological finds.

Here, we present new insights into the morphology and stable isotopic composition ($\delta^{13}C$ and $\delta^{18}O$) of soil rhizoliths from Luxor in order to: 1) establish Holocene rhizolith formation and palaeoenvironmental conditions on the banks of the Nile, and 2) produce a morphological framework of rhizolith development, applicable in Egypt and elsewhere. Findings will enhance our understanding of Holocene palaeoenvironmental change and human-environment interactions in the Egyptian Nile Valley, and inform rhizolith studies in other arid and semi-arid environments.

Active faults in La Palma (Canary Islands, Spain)

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During the 2021 La Palma fissural eruption, two faults were identified that controlled the distribution of earthquake hypocentres and lava emission centres. One of these faults has a NW-SE direction (Tazacorte Fault: FTZ) and the other one has an ENE-WSW trend (Mazo Fault: FMZ). Previous work of fault population analysis in La Palma (344 striated fault data distributed in 34 measurement stations; Rodríguez-Pascua et al., 2018 and 2019) indicated that the eruption zone was compatible with an extensional strain ellipsoid and normal-strike-slip directional faults, at the confluence of FTZ and FMZ. The fractures opened during the eruption were mapped in real time and there are more than 400 fracture data associated with the emission centres. Many of these fractures affect houses and studies carried out after the end of the eruption have shown that these two faults moved before, during and after the eruption. Some of the houses affected by the FTZ have been damaged 9 months after the eruption (these houses were not damaged during the eruption). These houses already had repairs made to the same fractures since 1980. The lack of seismicity after the eruption indicates that the movement of the faults is creep and that this was the type of movement they have had at least since 1980, with the exception of the eruptive process and the onset of seismic shocks in 2016. The mapping of these faults (FTZ and FMZ) is important in view of their application in the land use planning needed after the La Palma eruption of 2021.

Tectonic constraints as the origin of heterogeneity in seismic style: new analyses and simulations

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Faults are the boundaries where the slip between contiguous crustal volumes happens. The energy is mainly accumulated in the brittle lithosphere because of the action of tectonic and gravitational forces and it is released according to optimal dissipation criteria. The unbalance of stress components in the Earth's crust, based on the relative motion of crustal volumes, produces a wide pattern of heterogeneities in local tectonics and seismic dynamics. Thrust faulting events, usually featured by dip angles ranging between 5°-30°, mostly take place along convergent plate boundaries and are caused by the elastic strain accumulation, which is released by multifaceted fault slip dynamics, ranging from almost periodic silent events to mega-quakes. Strike-slip-faulting earthquakes localize along steeply dipping faults (70°-90°) or transcurrent plate boundaries and transfer zones. Finally, normal faults develop along rift zones in extensional regimes having intermediate dip (45°-65°), with a dominant gravitational contribution to their energy budget. Structural, morphological, and geophysical differences have been highlighted among the three main tectonic settings. Normal faults cause fracturing mainly concentrated in the hanging walls and spaced clusters of parallel faults across rifting areas. Fractured volumes host complex fluid circulation during the seismic cycle. Intricate geometries are also typical of transcurrent regions, often accompanied by releasing and restraining bends or step-overs and other geological structures shedding light on complex spatial stress patterns. Conversely, thrust-faulting earthquakes usually involve geometrically simpler seismogenic sources. We propose a simple mechanism for faulting inspired by the physical properties of granular matter and optimization criteria to explain differences in seismic activity depending on the tectonic setting: while the dynamics of compressive and transcurrent zones is driven by elastic strain, seismic activity associated with normal faults is mainly fuelled by gravity. Computational simulations support our hypotheses.

Stepwise, earthquake‐driven coastal subsidence in the Ganges–Brahmaputra Delta (Sundarbans) since the eighth century deduced from submerged in situ kiln and mangrove remnants

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This study reconstructs the coastal subsidence over the past 1,300 years in a mangrove region along the coast of the Ganges–Brahmaputra Delta, an area not affected by anthropogenic interference yet. The relative sea level (RSL) history is based on radiocarbon and luminescence ages measured on 108 submerged kilns and in situ mangrove stumps. While the regional, long-term average subsidence rate is calculated to be 2.7 ± 0.3 mm/yr, modern RSL (including eustasy, isostasy, ocean level, and subsidence) rises by 8.7 ± 0.4 mm/yr. This rate has been balanced by natural sediment accretion so far. A reduction in sediment supply by engineering projects along rivers and coasts may, however, accelerate coastal inundation and retreat. Subsidence has accelerated during specific episodes since the eighth century. A major land-sinking event happened in the eighteenth century, with a downward displacement of 1–2 m, depending on geographic area. We propose that the subduction related 1762 Arakan earthquake caused this sudden lowering. Prior to this event, RSL was nearly stable for 900 years. An earlier major subsidence event occurred around 900 CE, when the land suddenly sank by about 1 m, which also coincided with a major earthquake along the Arakan coast. Event-driven, sudden, significant subsidence, thus, needs to be considered a potential major hazard for coastal Bangladesh.

Plio- early Pleistocene re activation of Levant Fracture system. (Outer shelf,Offshore Lebanon)

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The eastern Mediterranean Levant Basin is an area where the effect of an adjacent major strike-slip fault in a complex geodynamical context can be tested. In the Lebanese area we explore the offshore expression of the Levant Fracture System (LFS) which are flanking long left lateral transform fault linked to the Dead Sea fault system. By using high quality 3-D seismic dataset and grounding our observations on a detailed seismic mapping of the Messinian to Pleistocene units we produce evidence of the LFS across the shelf edge along the offshore Lebanon. We do show that in addition to the well-known salt tectonic structures, there are clear offshore expression of the LFS which are deforming the Neogene unit (Messinian to late Pleistocene?). The structures in part re activate well known Mesozoic structures and are represented by both anticline and inverted structures. They deform both the Messinian Units (laterally pinching out toward the shelf) and the post Messinian contourite and deep-water system units mapped across the shelf edge . The structures are partly coeval with but un-related to the salt tectonic activity observed in the slope basin offshore Lebanon. We do provide and discuss good examples for those Neogene-Quaternary structures pointing that the main regional tectonic activities persisted to the early Quaternary across the offshore Lebanon.

The peculiar phreato-magmatic "jarosite deposit" in the island of Vulcano (Southern Italy): a significant impact, in terms of volcanic hazard

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A very peculiar thin reddish brown layer (on average between 2 cm and 0.1 mm) has widespread mantled most of the island of Vulcano, in Southern Italy, indicatively 500-1500 years B.P. when it was pratically uninhabited. The optical and scanning electron microscopic analyses show that this thin layer coat tit is composed of finely laminated amorphous material alternated with thicker lens-shaped layers with massive structure. The finely laminated portion contains high concentrations of S, Fe, K and Si, while the massive one consists primarily of glass fragments and microphenocrystals.

This deposit is so reasonably related to an eruption of phreato-magmatic type probably caused by the interaction between a magma batch (belonging to the high potassium series) which produced glass fragments and minerals in the massive portion, and a geothermal brine responsible of the formation of the finely laminated portion.

It is suggested that the involvement of a high saline component in the eruptive process generated a particular type of eruption comparable at a "hot hurricane", which have been characterized by relatively small quantities of material with a very high ejection energy. The pyroclastic reddish brown deposit formed during this event has been named "jarosite deposit" because of its considerable jarosite – $KFe_3(SO_4)_2(OH)_6$ – content.

The study of this peculiar phreato-magmatic material, which in the case of the island of Vulcano suggests has been ejected from a vent located to the north of the crater named Fossa.

The repetition of these events, due to the particular eruption type, would have a relevant impact, in terms of volcanic risk. The specific knowledge of these phenomena allows to better characterize the modalities and timing of the risks in insular and coastal volcanic areas, especially in highly populated ones.

Poster - sessions 6, 33, 145, 156, 160, 183

The case study of Corvo Island (Azores Archipelago) as a key for undersanding the shelf formation of ocean volcanic islands.

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Volcanic ocean islands are the present-day subaerial remains of much larger volcanic edifices that have grown from the ocean floor. Once the primary volcanic progradation is over, marine erosion (and mass-wasting) processes start dismantling the coastal areas and consequently form the island shelves. Shelf width and shelf edge depth can provide relative age constrains and eventual uplift or subsidence of the island. This work presents some quantitative preliminary results about the morphological evolution of Corvo Island (Azores Archipelago), through an integrated onshore/offshore approach. We interpreted data including subaerial (aerial photogrammetry, volcano-stratigraphy) and submarine datasets (multibeam bathymetry and high-resolution reflection seismics). This island basically consists on a main volcanic edifice so it can be considered a natural laboratory for understanding shelf evolution. The shelf surrounding Corvo is irregular both in width and edge, showing the widest and deepest erosive basement on its western side. A comparison between the assumed original volume of the subaerial edifice and its present volume allows estimating the total erosion on the island. Considering a maximum age of 1-1.5 Ma for Corvo, rough estimates of the erosional rates based on the shelf width were obtained. The Western shelf, being more exposed to waves, is wider than the remaining ones and so yields the highest values (1.87-2.80 mm/year). Differently, the analysis of cliffs erosion on the island of Corvo based on aerial orthophotos since 1955 till 2022, indicates values that are one order greater than the shelf rates. Once again, the western cliffs, being more exposed to marine erosion, are taller than the remaining ones and so yields the highest retreat (~0.9 cm/year). The comparison between short-time and long-time erosive rates is something that has never been done before. Therefore, these results will provide a more comprehensive understanding on the evolution of volcanic islands shelves.

Spatial variabily of nearshore clinoform bodies on the southern insular shelf of Madeira Island: the influence of sediment supply and inherited bathymetry.

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Nearshore clinoform bodies can be observed on the submarine parts of a variety of geological contexts such as continental margins and volcanic islands. These clinoforms have been suggested to form by wave action during storms that moves sediments from the nearshore and depositing them offshore where wave action falls behind the threshold of motion. On the bathymetry, clinoform bodies have a cross-shore sigmoidal geometry composed by a nearshore flat morphology (topset) separated from a steeper morphology (foreset) by a pronounced edge (rollover point). Further offshore, the steeper part of the clinoform gives place again to a flatter morphology (bottomset). On seismic profiles, their architecture is characterized by basinward surfaces that can either be obliqual or sigmoidal. The dimensions and shapes of clinoforms have been related with their depositional environments, including sediment supply, the energy of transport and grain sizes. Thus, their superficial and seismic characteristics allow understanding the hydrodynamism of the area where they developed. Madeira Island is an ocean volcanic island with a high relief and incised by a well-developed drainage mainly composed by torrential streams. Its southern shelf is not homogenous in what respects to its width, steepness and sediment grain-sizes. Although, the southern shelf is submitted to the same wave regime there is however, a great spatial variability of the nearshore clinoform bodies in what respects their dimensions, continuity, thickness and rollover point depths. The analysis of the bathymetry, seismic profiles and sediment grain-sizes, allowed the definition from west to east, of four different sectors, which are mainly controlled by sediment supply and the inherited topography, rather than wave energy.

Submarine sedimentary instabilities on the Palomares Continental Margin (W Mediterranean). Morphometry and distribution

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The Palomares Continental Margin, located in the Iberian Mediterranean margin, encompasses a narrow continental shelf (down to 120m water depth), and a continental slope that extends down to 2500m water depth. Different tectonic and sedimentary features at various scales define the heterogeneous, abrupt and irregular physiography of the margin. The most important features are the morphological highs (Aguilas, Abubacer and Maimonides); prominent submarine canyons (Gata, Almanzora-Alias-Garrucha and Aguilas); morphosedimentary features associated with contour currents (mainly in the continental slope) and sedimentary instability deposits of different size distributed throughout the margin.

The analysis of medium and high resolution, 50m and 15 m respectively multibeam bathymetric data has allowed to build a regional inventory of 937 events of sedimentary instability, defined by their scars and head areas. Mass-wasting affect more than 821 km^2 and mobilize approximately 10.34 km^3 of sediment along the margin. Regional-instabilities inventories are very useful quantifying the role of these processes in the geomorphologic evolution of one area but also constitute a first step towards the assessment of landslide-related hazard. In addition to size, other morphometric parameters such as scar length and sinuosity, head area, regional gradient, scar height and scar gradient have been included in the inventory to have a good selection of variables that characterize the instability events.

Statistical analyses revealed that the cumulative distribution of the landslide area can be characterized both by inverse power and log-normal distributions. In the first case, a partial fit is achieved explaining two orders of magnitude (major events) of the whole dataset. The log-normal function is adjusted to the entire sample events. This fact would lead to define both a characteristic event size determined by the geomorphological conditions and a variance linked to the characteristics of the main triggers that in the area would be the earthquakes.

Liquefaction and evolution of the shallow Garrucha submarine canyon head

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The aim of this work is to establish the role of liquefaction on the shallow Garrucha submarine canyon head, in the W Mediterranean Sea. A geotechnical approach has been used to determine the liquefaction potential, combining *in situ* CPTu data as well as undrained cyclic direct simple shear (UCDSS) laboratory tests on sediment cores. All the data have been analysed considering the simplified procedure for evaluating soil liquefaction potential. The use of both, laboratory and CPTu tests for liquefaction assessment increase clearly the confidence of the results obtained.

Sediments sampled around the canyon head are sands with a very low fine sediment and without plasticity. Three series of UCDSS tests were carried out under vertical loads equivalent to 1.8 m, 3.7 and 12.3 meters below sea floor (mbsf) and the results indicate that liquefaction is clearly possible in the area. On the other hand, the cyclic resistance ratio (CRR) provided by the CPTu tests for depths up to 20 mbsf confirmed the liquefiable character of the sediments in the area specially at depths of more than 3 m below seafloor and where low-permeability intervals intercalated are detected.

The high probability of triggering liquefaction processes highlights a phenomenon normally underestimated in submarine environments. This process may be associated to minor morphological effects or major morphosedimentary consequences that may be involved in the evolution of the canyon head as well as the downslope transport of sediment stored on the upper part of the canyon.

The results reported here are also significant in terms of the shallow environment studied and the proximity of coastal infrastructures such as the Garrucha harbour. This implies that any stability model for hazard and risk assessment must include the dynamic properties of the sediments.

Seismic stratigraphy and geological structure of the Plio-Quaternary deposits on the Korea Strait shelf, Korea: Implications for tectonic effects and sea-level changes

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On the basis of high-resolution seismic data from the Korea Strait, the shelf sequence consists of four seismic units, namely, Pliocene (III), Lower Pleistocene (IIB), Upper Pleistocene (IIA), and Holocene (I), respectively. Vertically, with the exception of unit I, the units show a series of superimposed prograding wedges that thicken seaward. A structural high, including several faults and folds, occurred in the northern part of the Tsushima Island, extending northeastward to the Dolgorae Thrust Belt at the southern margin of the Ulleung Basin. In this study, we deduced that the deformed zone was formed due to compressional deformation associated with back-arc closure that occurred after the extension of the East Sea. Most of the faults and folds oriented in NE–SW or NNE–SSW directions mainly developed in the lower two units (III and IIB). The lower two units were also significantly deformed, whereas the two overlying units remained relatively undeformed. This indicated that, during the Pliocene and Lower Pleistocene (units III and IIB), sedimentation was mainly controlled by tectonic activities, whereas sedimentation after the Lower Pleistocene (units IIA and I) was mainly influenced by periodically repeated sea-level changes rather than tectonic effects.

A morphotectonic investigation targeting an onshore and offshore setting: methodologies and examples from a preliminary case study on the Maltese archipelago

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The last decade has seen a growing interest for the geomorphic research to integrate datasets from multidisciplinary and interdisciplinary techniques. This approach is particularly effective when working at the geomorphic evolution of coastal areas, Quaternary developments, and geohazard analysis. Our contribution reveals the first attempt of a tectono-geomorphic analysis for the areas onshore and offshore of the Maltese Islands, extending the use of common techniques for terrestrial morphometric analysis to the area offshore. For the offshore portion, a mosaic of three datasets was created and then resampled at the resolution of 30 m in order to increase the computational efficiency of our analysis. This dataset was obtained from a combination of surveys carried between 2012 and 2021 (including bathymetry retrieved from research cruises and airborne LiDAR). The dataset for the area onshore, originally at the resolution of 3 m, was also resampled at 10 m and then at 30 m, to guarantee consistency with the analysis of the dataset offshore. The morphometric analysis was performed at the resolution of the final dataset (30m) but also re-ran at finer resolution across those portions of the study area that allowed a higher resolution in data. The dataset obtained was refined for hydrological analysis by applying smoothing filters, voids fillings and artefacts removal. Our results revealed that the river organization appeared as dendritic for the onshore portion of the island of Gozo, while it turned to be trellis and oriented parallel to the strike (NNW/SSE) of the major structural feature of the offshore graben on the east side of the archipelago. In addition, the streamnet followed an E-W orientation across the onshore portion of the Island of Malta, in agreement with the predominant structural features observed. Low values of river steepness index (K_{sn} <10) for both the offshore and onshore areas are measured, while knickpoints are largely concentrated where high differences in the topographic gradient are recorded, in coincidence of lithological contacts, structural features and gullies erosion. This preliminary investigation links the drainage anomalies outlined by knickpoints and *Ksn* with a tectonic and/or climatic cause that could explain its neotectonic evolution.

Reconstruction of former landscapes and Late Quaternary sea level changes in the Krka River mouth area

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Most of the eastern Adriatic rivers have cut their rocky canyons for the last time during the Last Glacial Maximum (LGM). In that period the sea level was up to 130 m lower than today and karstic rivers originated as incised valleys, with a sediment bypass to the shelf and formation of a delta at their river mouths. The Krka River mouth on the eastern Adriatic Coast (EAC) went through intensive paleoenvironmental change since the LGM. The paleoenvironments evolved from an offshore extensive alluvial plain and a lowstand shelf-edge delta in the area between the island of Žirje and the mainland, to the present-day onshore salt-wedge karst estuary and the Skradinski buk tufa waterfalls. The architectural units and paleoenvironmental changes were studied by a multidisciplinary approach, combining multibeam, seismics and dated sediment cores.

In the area of lowstand alluvial plain and shelf-edge delta a total of 37 seismic profiles were recorded, while in the incised valley and present estuary a total of 119 seismic profiles were recorded and correlated with seven long sediment cores. The deltaic deposits consist of stacked progradational wedge-shaped units with penetration of acoustic signal up to 40 m.

Postglacial sea level rise (approx. 17000–7000 y BP) flooded a wide delta with a formation of shallow brackish environments and an early Holocene estuary between the island of Žirje and mainland. Furthermore, during that period favorable conditions were established for freshwater tufa barriers growth and the deposition of fluvio-lacustrine sediments in the onshore part (Prokljan Lake). In continuation of rapid sea level rise, the sea started to flood Prokljan Lake and the tufa waterfalls at the beginning of the Holocene with a formation of the salt-wedge estuary and deposition of marine/estuarine sediments at approx. 7000 ky BP.

This study highlights the complexity of investigated system which is under the control of several factors, mainly the sea level changes, climate, sediment supply and geomorphology and offers a valuable new results and information on sea level changes and paleoenvironmental variability along the EAC.

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Insular shelves as proxy for reconstructing Late-Quaternary local sea-level and paleogeographical changes in volcanic islands

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Insular shelves on volcanic islands form essentially through marine erosion of edifices during stages of reduced or inactive volcanism, and are representative of their original extension. In particular, the shelf edge is a marker of the relative sea level at the moment of shelf formation, being a useful indicator of the interaction between tectonics, volcanism and sea level changes.

The distribution and morphological characteristics of the insular shelves around Salina Island (Aeolian Arc, Southern Italy) including the shelf-edge depth, are taken as a proxy for the relative age attribution of the volcanic edifices on which they were carved, giving insights on the chronological development and early emergence of the island. Larger and deeper shelves (shelf edges over 125 m depth) experienced wave erosion during successive sea-level fluctuations and subsidence after their formation, and are thus indicative of a relatively older age of the eroded volcanic edifices, largely dismantled and, in some cases, not more documented on land. Narrower shelves have a lower evolutionary maturity and formed where younger volcanic edifices are present. Their shelf edges, mostly lying at -110 m depth, suggest that these coastal sectors were relatively stable after erosion during the Last Glacial Maximum. By integrating these data with onshore geological field studies, we estimated relevant paleo sea level positions from i) the erosive shelf edges recognized offshore at different depths and ii) the raised terrace inner margins exposed subaerially at different elevations. Compared with the eustatic sea levels at the main highstands (for the raised terraces) and lowstands (for the submerged shelf edges) derived from the literature, these paleo sea level markers allowed us to quantify the pattern, magnitude and rates of vertical movements affecting the different sectors of Salina since the time of their formation. The crustal vertical deformation through time shows alternating uplift and subsidence, respectively outlined for the last 124 ka (MIS 5.5, Last Interglacial) and for the time interval between 465 ka (MIS 12) and 124 ka). This behaviour likely suggests a major tectonic and geodynamic change and variation of the stress regime acting on the Aeolian sub-volcanic basement.

Uranium series disequilibrium(238U-230Th) dating of zircon in trachyte from Jeju island, South Korea

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Uranium series disequilibrium dating (^{238}U-^{230}Th) has been considered an attractive tool for Quternary volcanic rocks dating. In Jeju Island, South Korea, there are many Quaternary volcanic rocks that can be used for uranium series disequilibrium dating. Among them, trachytic rocks are observed in Mosewat trachyte in the northwestern part of Backrokdam in Mt. Hallasan, Hangpaduri in the north of Jeju Island, and Jejigioreum volcanic cone in Bomok port, Seogwipo-si.

In this study, Cl imaging and uranium series disequilibrium dating of zircons mineralized from trachytic rocks collected from 6 areas in Jeju Island, including Mosewat trachyte, were performed using Laser Ablation Multi Collector Inductively Coupled Plasma Mass Spectrometer(LA-MC-ICPMS) of the Korea Basic Science Institute. The analysis conditions of LA-MC-ICPMS were 30 μm for beam size, and the analysis time was 30 sec. The analysis points of zircon grain ranged from 16 to 34 depending on the rock body.

Among the analyzed samples, trachyte rock with the oldest age, Jejigioreum showed an age of 296Ka, and Mosewat trachyte showed a younger age of 28.8Ka. Jeju Island is a volcanic island located at the southern edge of South Korea and represents a volcano located on the Eurasian continental margin. We will report the ^{238}U-^{230}Th age dating of zircons from the Middle Pleistocene to the Holocene and discuss their mineralization time scale and the formation history of volcanic stratigraphy.

Quaternary volcano-tectonic morphology in the lower slope of Canary Islands (Canary Basin)

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The eastern side of the Canary Basin (NE Atlantic Ocean) corresponds to the interference of the western Africa continental margin and a volcanic seamount-islands chain. The lower slope is developed to the west of the Canary Islands. This slope segment is characterized by the influence of several processes: tectonism, volcanism and mass transport deposition. It has been differentiated morphological elements of tectonic, volcano-tectonic, and volcanic origin controlling the current seafloor and the sedimentary flows of the lower slope.
Most of the differentiated structural features correspond to linear scarps and ridges following NNE-SSW trends. They are interpreted as subvertical faults, mostly normal, and subparallel anticline-syncline to monocline folds, respectively. In addition, pronounced escarpments and related wide linear depressions cross the area with WNW-ESE to W-E trends, which are formed concerning oceanic fracture zones. Volcano-tectonic reliefs include the Garoé bulge which is a kilometric-scale structure, 78 m high, with an elliptical shape that is crossed by normal faulted depressions in its summit and flanks; and subcircular to elongated domes are identified due to the merging of several structures, with predominant NE-SW trends. Both types of structures have been related to sills intrusions. Finally, volcanic edifices are constituted by hundred of mounds, hills and seamounts. Mounds are distributed in NNE-SSW trails although isolated edifices are also observed. Their shapes vary from subcircular cones to mostly irregular and elongated crests. Hills and seamounts are randomly distributed in the study area but they are WNW-ESE aligned in the Southern Canary Islands Volcanic Province. They have a great variety of shapes, mostly irregular and ellipsoidal although some elongated ones are also identified. They are built by magmatic and/or hydrothermal extrusion events.
The trends of these tectonic and volcanic reliefs matching with the oceanic fabric, NNE-SSW normal faults related to old ocean spreading axis, and WNW-ESE oceanic fracture zones evolved from transform faults. The current expression on the seafloor corresponds to a volcano-tectonic activity from the Middle-Late Miocene to the Quaternary. This morphological model is a study case for deeply slope areas controlled by tectonic deformation and volcanic activity during the Quaternary.

Geomorphology and sub-surface stratigraphy of a Mediterranean shelf receiving minor fluvial input: The imprint of relict landscapes

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Narrow continental shelves such as those surrounding the Mediterranean basin are usually dominated by active depositional features such as major prodeltaic wedges located off major rivers (e.g. the Gulf of Lions, the northern Adriatic Sea), or by infralittoral wedges in settings where fluvial supply is more limited and hydrodynamic regimes are more energetic. However, the knowledge of the geomorphological patterns of undernourished shelves remains much less documented. In this contribution, we aim to characterize the submarine geomorphology and the sub-surface sedimentary bodies of a shelf sector located west of the Guadalfeo River, a major regional source in the northern margin of the Alboran Sea, where fluvial supply is provided by small seasonal rivers. To reach those goals, we analysed a data base comprising multibeam bathymetric and backscatter data, seafloor video images and Parasound acoustic sections.

The studied shelf exhibits a distinctive zonation, where three major domains could be characterised. In the inner shelf, the most significant depositional bodies are composed by wedge-shaped deposits with limited lateral extent. Over the surface, several geomorphic indicators reveal the occurrence of high-energy processes in relation to the seasonal inputs of the Verde and Seco rivers. Recent to modern sedimentation seems to be much reduced distally. The middle shelf is marked by two main breaks of slopes, the surficial expression of highly reflective depositional bodies, likely marking the location of ancient paleo-shorelines and extensive development of paleo-coastal plains. The outer shelf is a flat domain covered by several elongated sedimentary bodies, which are disposed oblique to the middle shelf paleo-shorelines. Below those bodies, sub-surface architectures exhibit several unconformity-bounded regressive wedges.

We discuss the shelf zonation observed in the study area considering the confinement of recent infralittoral and prodeltaic wedges to the inner shelf, the preservation of ancient landscapes in the middle shelf, and the record of sediment transport dynamics during postglacial phases of shelf flooding in the outer shelf.

Insights into the 1977 Gioia Tauro Landslide: role of shelf indenting canyons and submarine depositional terraces.

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Submarine landslides are a major threat for coastal infrastructures. A key example is the event occurred on 12th July 1977, when tsunami waves up to 5 meters high hit the coastline during the construction of the port of Gioia Tauro, (Southern Tyrrhenian Sea, Italy), causing severe structure damages. The event is still poorly understood because of lack of detailed data before the landslide and paucity of scientific studies afterwards. In this study we combined literature data, unpublished technical reports, detailed historical and present-day bathymetric analyses to achieve a better comprehension of the event dynamics.

Results show that: (1) a canyon head is present in front of the port and the seabed is, and was before the slide, characterized by the presence of a submarine depositional terrace (SDT) all along the coastline, made up of prograding sand and gravel; (2) before the failure event, a large amount of sediments derived from port excavation was progressively dumped within the canyon head and above the SDT. This generated a partial infilling of the canyon head and increased the progradation of the SDT; (3) the landslide caused both the collapse of dumped sediments, mainly within the canyon head, but also the failure of a ~2km stripe of SDT on the neighboring coastline; it is worth to notice that the failure affected not only the dumping but also the sediment pre-existing port construction. Therefore, we hypothesize that the Gioia Tauro event was a complex progressive submarine landslide starting at canyon head and propagating retrogressively toward the SDT. The landslide was probably triggered by the weight of the dumped material above the SDT that was present inside the canyon head. Then the failure affected the SDT outside the canyon and this probably played a key role in tsunami propagation. We conclude that submarine depositional terrace may play a relevant role in the generation and propagation of nearshore tsunamigenic landslides. Further studies on these sedimentary bodies are therefore extremely relevant for marine geohazard assessment.

Sedimentological and morphological expressions of glacial floods in the area of the Saalian Glaciation in Poland

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Glacial floods constitute a very important factor in shaping the forelands of contemporary glaciers. They also had a large-scale impact on areas glaciated during the Pleistocene – both during the most recent glaciation (Weichselian, Vistulian), and – as indicated by the latest research in Poland – also in the area of the Saalian Glaciation.

The most typical sediments interpreted as traces of glacial flood in the analysed area include the following: massive gravels and boulders, gravels and boulders with normal and reverse grading, matrix-supported massive gravels, planar cross-stratified gravels with boulders, low-angle and horizontally stratified gravels and sands. These sediments fill, often completely, erosional channels. They also occur in the form of continuous fluvioglacial covers. Common, characteristic forms include gravel dunes of up to 2.5 m of height, usually buried. Coarse-grained flood sediments are often found near fine lacustrine sediments, resulting in density deformations. Morphological record of glacial floods in the study area is generally sparser than in the areas of the Weichselian Glaciation. It underwent considerably more prolonged modifications from various morphogenetic factors (fluvial and aeolian erosion and accumulation, processes related to the occurrence and degradation of long-term permafrost, denudation processes). The most distinct forms include erosional valleys, cut into end moraines and moraine plateaus, which carry off water in the glacier foreland, and which are contemporarily drained by disproportionately small watercourses. Their widths reach up to 2-5 km. The presence of erosional terraces and several generations of suspended cuts indicates that these runoff paths were used multiple times during flood events. Traces of a glacial flood in the outwash plain have been preserved in the form of numerous kettle holes left after melted blocks of dead ice, and indistinct dunes of 0.5-1 m of height with an amplitude of 60-70 m.

As follows from the research done by the authors in recent years, the impact of glacial floods in areas of the Saalian Glaciation in Poland was significant. The sedimentological record of these processes is very well preserved, whereas in relief it is varied as a result of various long-term destructive processes of the postglacial period.

Morphological characteristics of eskers in Poland

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The purpose of the research is to conduct morphometric analysis of approximately 300 eskers in Poland, to the south of the Last Glacial Maximum. The analysed forms originated during the Saalian and Elsterian glaciations. There is still insufficient knowledge about eskers formed within the extent of ice sheets older than the Weichselian or Wisconsin Glaciation. Studies tend to focus on areas with a high density of eskers formed on hard bedrock. Eskers of the study area were formed on permeable, soft bed, composed of glacial and glaciofluvial sediments. The eskers were delineated on the basis of the Detailed Geological Map of Poland 1:50 000, topographic maps 1:10 000 and DEM 1m. The morphological analysis included their length, maximum width, elongation, fragmentation, sinuosity, orientation, presence of tributary ridges and their order. In the analysed area of Poland, eskers of 1-3 km in length prevail. The maximum length slightly exceeds 10 km. They are characterised by the average maximum width of 250 m and slight predominance of straight over sinuous forms. They are built of elongated ridges with only 15.5% of gaps in their total length. 35% of eskers have tributary ridges of maximally second order. The distribution and morphological characteristics of eskers of the study area were mainly influenced by the origination of forms on a permeable substrate. The eskers' features support the theory of predominance of the synchronous model of esker formation in this area. Morphological parameters depend on complex genesis of some eskers and superimposition of open crevasse sediments over the subglacial facies. The important factor is the formation of eskers during older glaciations (MIS6-12) and their subsequent transformation and erosion under variable climatic conditions. The presented study broadens the knowledge of eskers originated during older glaciations. It also provides new insights into the nature of esker formation and subglacial meltwater drainage in the area of soft bed.

Distribution and age of periglacial ramparted depressions in East Anglia, United Kingdom

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Relict periglacial ramparted depressions (PRDs), believed to be pingo scars, are mapped extensively across East Anglia (United Kingdom) using LiDAR and field surveys, and their topo-climatic origins, relative age, and evolution are examined.

Pingos are a type of ice-cored hill that develop in permafrost, i.e. perennially frozen ground. They are formed either where water is injected upwards under hydraulic pressure, or where water that is trapped between layers of frozen ground becomes pressurized and subsequently erupts upwards. PRDs are thawed products of ice-cored hills, and are characterised by ramparted, circular depressions. However, PRDs may be expressed in a variety of forms due to erosional/depositional histories – especially where agricultural practices have altered the landscape.

PRDs (~10-30 m diameter) are identified across East Anglia and can be used for reconstructing former permafrost environments and palaeoclimates. PRDs are concentrated in valleys and scattered across hillsides, suggesting pingo formation favoured wetter environment as expected in the valleys. Pingo formation is thought to have occurred during the Late Devensian (MIS 2) when the last British Ice Sheet flanked the East Anglian coastline; pingo degradation, and subsequent PRD formation, likely occurred during the Younger Dryas-Holocene transition (*c.* 11.7 ka) in response to climate warming.

This dataset of PRDs can also be used to better understand human-landscape interactions. Extant PRDs in coppiced woodland contain ephemeral ponds, suggesting that numerous pond environments may have existed across East Anglia throughout the Holocene. Archaeological remains such as heat crackled flint and bone found within and adjacent to PRDs suggests humans have utilised and/or infilled ramparted depressions across the landscape, perhaps for thousands of years.

New data about timing of late Weichselian Scandinavian Ice sheet (MIS-2) in northeastern Germany - lithostratigraphical investigations of tills and OSL-datings from a pipeline trench

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The NEL gas pipeline trench gave in 2012 excellent insights into the uppermost Quaternary sections. Several sites across the basin were sampled for lithostratigraphical investigations of uppermost till layers, local sedimentological investigations as well as dating by OSL.
According to several new published OSL results in Mecklenburg-Vorpommern at southwestern Baltic Sea coast the Scandinavian Ice Sheet (SIS) reached its Last Glacial Maximum (LGM) during Marine Isotope Stage 2 (Brandenburg-phase, MIS-2). In general the ice front retreated from this position, interrupted by several short periods of readvance or stillstand during e.g. the Frankfurt(Oder)-subphase or the transgressive Pomeranian phase (c. 20-19 ka). For till gravel composition and lithostratigraphy from uppermost till layer several samples has been taken for petrographical analysis of small gravel till clasts using former GDR standard TGL 25232 (1971, 1980). The majority of samples from upper till contains clasts from eastern Baltic region e.g. Palaeozoic limestones and to a minor extent of sandstones, quartzites ,and Palaeozoic shales (PS), and representing a typical till clast composition of tills of Late Weichselian glaciation (MIS 2).
Local results from 'Dobbiner Plage' indicate that during deglaciation of the Frankfurt(Oder)-subphase (W1F), a river system and a local ice-dammed lake existed in the glacigenic depression. The glaciofluvial phase of W1F-deglaciation is represented by cross bedded gravelly sand deposits and has been OSL dated to ~21 – 20 ka. On top of the glaciofluvial sequence, periglacial structures like meso-scale frost cracks and large-scale frost wedge pseudomorphs with maximum of 2 m depth were detected. The OSL dates suggest that cover sands (mainly aeolian) infilled the open ice wedges between 19.5 – 17.3 ka. The timing of periglacial encroachment with opening and filling of ice wedge polygons therefore well correlates with cooler period of Pomeranian ice transgression phase (W2) and the beginning deglaciation.
OSL measurements were performed on quartz of the fine to medium sand fraction (90-200 µm) using a standard SAR protocol on 2-millimeter aliquots. The OSL properties of the measured quartz were good and in most cases the grains were well bleached during the last sedimentation cycle as shown by the narrow paleodose distributions.

Ice buttressing controlled rock slope failure on a cirque headwall, English Lake District

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Rock slope failures in the English Lake District have been associated with deglacial processes after the Last Glacial Maximum, but controls and timing of failures remain poorly known. A cirque headwall failure was investigated to determine failure mechanisms and timing. The translated wedge of rock is thin, lies on a steep failure plane, and yet the friable strata were not disrupted by downslope movement. Fault lines and a failure surface, defining the wedge, were used as input to a numerical model of rock wedge stability. Various failure scenarios indicated that the slope would have failed catastrophically, if not supported by glacial ice. The amount of ice required is insubstantial, indicating likely failure during thinning of the cirque glacier. As ice retreated, the wedge was lowered slowly down the cirque headwall slowly exposing the failure plane. A ^{10}Be exposure age of 18.0 ± 1.2 ka from the outer surface of the wedge indicates late Devensian de-icing of the back wall of the cirque, with the upper portion of the failure plane exposed at 12.0 ± 0.8 ka. These dates suggests that a small buttressing ice mass lingered in the cirque for several millennia after general deglaciation of the area. The exposure age of 12.0 ± 0.8 ka represents a minimum age, as the highly-fractured failure plane likely experienced post-failure mass wasting. Considering the dates, it appears unlikely that the cirque was re-occupied by a substantial glacial ice mass during the Loch Lomond Re-advance or during the Younger Dryas Stadial.

Szymon Śledź, Marek W. Ewertowski, David J.A. Evans

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Proglacial areas belong to one of the most dynamic landscapes and are important indicators of changes related to climate warming. Systematic observation of landforms in the glacier forelands, combined with measurements of changes in their volume, allows for estimating the rate of the changes taking place and a better understanding of the processes that generate these changes. In this study, short-term (2014, 2016, 2021, 2022) transformations of the proglacial landscape in front of Kvíárjökull, SE Vatnajökull, Iceland, were quantified using a time-series of unmanned aerial vehicle (UAV) surveys processed through structure-from-motion (SfM) workflow to produce digital elevation models (DEMs) and orthomosaics. We selected four areas representing different landform assemblages: kame terraces, outwash plain, ice-cored moraine complex, and ice-cored pushed moraine arc and calculated elevation and volumetric changes. Kame terraces between 2014 and 2022 and outwash plains between 2016 and 2022 were mainly stable, with 81% and 95% of their surfaces which did not undergo any changes. Ice-cored pushed moraine arc recorded a volume loss of 65 538 m^3 in 2016-2022, and maximum surface lowering was up to 8.8 m. The most dynamic was the ice-cored moraine complex, with transformation recorded for more than 87% of its area in 2014-2022. The surface of the ice-cored moraine complex lowered up to 19 m, and the total volume loss was 390 977 m^3. The most dramatic changes were related to the rapid degradation of dead ice blocks and, to a lesser extent, water erosion by small streams and mass movements. We also propose a conceptual model for the development of ice-cored moraine in a short time scale, pointing to possible end effects of its evolution.

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Glacial features map database of Finland produced using LiDAR data interpretation

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The glacial features map database workflow utilises LiDAR data produced by National Land Survey of Finland. The point cloud density is 0,5 points per square metre. The point cloud data was processed at the Geological Survey. In the interpretation work the main LiDAR data derivative used is the Multidirectional hillshade, but also slope is used. The primary DEM data is also used to visualise the height differences.

Additionally extensive other data is used in the interpretation: topographic data, aerial photos, earlier mapping (Quaternary geological maps 1:20 000, 1: 100 000, 1:200 000), Aggregate resources mapping data, field observations, borehole data, field geophysics (refraction seismics, GPR, and gravity profiles).
The map database format is ESRI geodatabase and the software used are ArcMap and ArcGIS Pro. Database main elements are the glaciofluvial and moraine deposits and the glacial lineations (over 330 000 lineation polylines). Additionally, for practical reasons the littoral (shoreline) deposits are included. Currently work is progress to produce the eolian deposits, mainly the dune fields.

For the glaciofluvial deposits (over 100 000 polygons) the main classes are the eskers and the ice-marginal deposits, but the extramarginal deposits are also included. Esker areas are further divided to subclasses, as are the ice-marginal deposits.
The moraines (diamicton-dominated deposits) (over 82 000 polygons) main classes are the ribbed moraines, and hummocky moraines. Hummocky moraines are further divided into subclasses, which include the subglacially formed and ice-contact hummocky moraines. De Geer moraines and other diamicton-dominated end moraines also have their classification system. Work has started to delineate the murtoo and pulju deposits.
The map database can be studied using the Geological Survey of Finland (Geologian tutkimuskeskus = GTK) map server, from the web address: https://gtkdata.gtk.fi/maankamara/ (in Finnish, look for Jäätikkösyntyiset maaperämuodostumat), there is additionally hillshading data you can combine with the Glacial Features data, it is Varjostettu korkeusmalli in the Table of Contents. You can also download the map database from the GTK Hakku service: https://hakku.gtk.fi/en/locations/search and search for Glacial features.

Iceberg ploughmarks on the Norwegian shelf

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Inspection and mapping of large volumes of high-resolution multibeam echo-sounder data (30 000 km^2) on the Norwegian shelf have revealed many different types of iceberg ploughmark, illustrating several processes linked to both ocean currents and tidal influence. We have mapped the total population of iceberg ploughmarks in a number of areas and produced statistics on the size and direction of the individual ploughmarks. From this, the palaeo-current pattern from the last deglaciation of the Norwegian shelf has been reconstructed, c. 15 – 20 000 y BP. Many sets of single- and multi-keeled ploughmarks are presented from the Norwegian continental shelf and slope with the largest up to 2 km wide and with more than 10 protruding keels. Several iceberg ploughmarks with well-developed chains of regularly spaced pits have been mapped on the upper mid-Norwegian continental slope in 400-500 m water depths. The pits are interpreted to reflect a tidal imprint by the grounding of icebergs at successive low tides, allowing the drift velocity of the icebergs that formed the ploughmarks to be calculated. The distance between pits varies between 70 and 175 m giving an average drift velocity of between 5 and 15 m hr^{-1}. The pits are asymmetrical and often have a downstream berm, making it possible to determine the direction of iceberg drift and, thus, the current direction at the time of ploughmark formation. The general drift direction during deglaciation is similar to the direction of the modern North Atlantic Current. A large proportion of the ploughmarks on the continental slope of the mid-Norwegian shelf were probably produced by icebergs from the Norwegian Channel Ice Stream during deglaciation.

Inter-ice stream moraine belts: implications for Quaternary palaeoglaciology

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Expansive areas of complex glacial landform assemblages, dominated by glacitectonic compressional structures and hummocky terrain, constitute a long recognised landsystem signature of ice sheet recession on the North American prairies often generically labelled as "moraine belts". Such belts separate the more elongate and streamlined zones that constitute the footprints of the former palaeo-ice streams of the SW Laurentide Ice Sheet and hence have more recently been referred to as inter-ice stream regional moraine zones, constructed during regional deglaciation. These inter-ice stream moraines are characterised by: 1) spectacular glacitectonic compression of bedrock, cupola hill construction and mega raft displacement; 2) multi-phase stagnant ice melt-out related to partially overprinted surge lobes; 3) kame and kettle topography related to the development of glacier karst and the production of eskers contemporaneous with lobe overprinting; and 4) widespread enigmatic landforms such as prairie doughnuts, doughnut chains, artesian blow-out features and possible till eskers. The latter have traditionally been related generically to supraglacial processes but we propose that they are predominantly the product of groundwater pressure variability and potentially biogenic shallow gas escape driven by deglaciation of the low permeability Cretaceous bedrock, where ice flow was against an adverse bed slope. Landform patterns also indicate that larger areas of hummocky terrain are not chaotic but rather comprises hummock chains that parallel the receding ice sheet margin and hence are related to ice-marginal processes. Complex stratigraphies and landform palimpsests also indicate that the moraine belts may contain older marginal landform assemblages likely dating to more restricted ice sheet extents that pre date the last glaciation.

Using high resolution 3D morphometry to understand the spatiotemporal properties of de Geer moraines and evaluating their potential to refine palaeo-ice marginal reconstructions of the Fennoscandian Ice Sheet

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De Geer moraines (DGMs) have the potential to generate very high-resolution, spatial and temporal, ice margin reconstructions (~annual in contrast to 100-500 years, the current state-of-the-art), however, formational processes remain poorly understood. Existing studies suggest that DGMs likely form annually, in association with the seasonal cycles of glacial advance/retreat. Specifically, it is suggested that formation occurs in a subaqueous, ice-marginal environment whereby basal sediments are advected and deposited at the grounding-line during seasonal advances. However, there have also been suggestions of a crevasse-fill origin that challenges this temporal regularity. Whilst the spatiotemporal properties of DGMs are disputed, the balance of evidence suggests an ice-marginal depositional environment with annual/seasonal regularities. This is critical, as it suggests that DGMs may be able to delineate ice-marginal retreat at unprecedented (potentially annual) resolutions. We attempt to constrain the spatiotemporal properties of DGMs by undertaking a highly detailed 3D transect-segmented morphometry study in the Fennoscandian Ice Sheet area. Here, we present the results of a high-resolution (2 m), large sample (n > 9,000) study of DGM morphometry across a study site located in SW Finland. This 3D transect-segmented morphometric approach provides a powerful method in which to analyse DGMs at large scales and in considerable detail. High resolution digitisation of DGM outlines and crestlines allows the quantification of several geometrical parameters including: length, width, height, volume, sinuosity, slope, and cross-sectional asymmetry. In addition, spatial distribution characteristics were assessed using a cluster analysis approach which allows for a deeper understanding of environmental prerequisites and formational controls. The results may be used to: 1) inform process models of DGM genesis, 2) provide a robust dataset which can be extrapolated for discriminative/classification studies against similar landforms (i.e., crevasse-squeeze ridges), and 3) evaluate DGM potential to refine palaeo-ice marginal reconstructions.

New metrics reveal the evolutionary continuum behind the morphological diversity of subglacial bedforms

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Understanding the evolution of subglacial bedforms is critical to constrain ice-meltwater-bed interactions and the dynamics of past and present ice sheets. However, the difficulty to monitor active subglacial bedforms below present-day ice sheets implies that their evolution are essentially deduced from the inversion of morphological data from palaeo-subglacial bedforms. In this study, the morphological characteristics of subglacial bedforms are explored through a new approach based on the combination of three dimensionless morphometric indices i.e., circularity, sinuosity and oriented elongation.
From two selected portions of the Irish Ice Sheet and Laurentide Ice Sheet beds, we measure the spatial distribution of morphometric indices on an unpublished database composed of ~13 500 digitized subglacial bedforms considering (1) they were all formed under a single ice flow configuration in each region and (2) they may have developed either orthogonal, parallel, or oblique to ice displacement directions. Our results demonstrate the existence of a morphometric and spatial continuum of subglacial bedforms behing a larger morphological diversity than currently postulated in the litterature. In this continuum, ribbed bedforms – ranging from circular to elongated flow-transverse forms – are incipient bedforms that can evolve into transitional sinuous ribbed bedforms, then into predominantly flow-parallel sinuous bedforms, which progressively realign to form increasingly elongated streamlined bedforms. Considering the glaciological contexts of selected study areas, this continuum may provide new geomorphic criteria to constrain spatial variations in subglacial conditions (e.g. ice flow velocity, bedrock characteristics, meltwater pressure).

Chronology and morpho-climatic history of large rock slope failures in the Southern Swiss Alps

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Large rock slope failures in Alpine environment are influenced not only by structural weaknesses inherited from tectonics and lithological characteristics of slopes but also by the climate history. The glacial history plays a significant role in slope stability, as the glaciers' pressure exerts a variable load on the valley flanks and reduces the slope strength, often leading to rock slope failures.

In the Southern Swiss Alps, in the territory of the five valleys north of Bellinzona (Riviera, Valle Leventina and Valle di Blenio in Canton of Ticino, Val Calanca and Valle Mesolcina in Canton of Graubünden), several deposits of large rock slope failures can be observed. A detailed geochronological assessment of glacial retreat and the age of slope collapse is essential to understand the strong relationship between the two phenomena.

This research aims to define the exposure age of the rock slope failure deposits considered Prehistoric through Schmidt hammer exposure-age dating and analyze the achievements in relation to the collapse volume to assess their morpho-climatic evolution.

Exposure ages indicate collapses just a few centuries/millennia after the deglaciation (dated between 16.94 and 16.25/15.96 ka b2k for the lower and middle parts of Mesolcina, Blenio and Leventina valleys). Both deglaciation and dated rock slope failures occurred during the Greenland Stadial GS-2.1a of the INTIMATE event stratigraphy, dated between 17.48 and 14.69 ka b2k (Rasmussen et al. 2014, Quat. Sci. Rev. 106) or, at least, at the beginning of the Greenland Interstadial GI-1 (14.69–12.90 ka b2k), in particular during the events GI-1e (14.69–14.08 ka b2k), GI-1d (14.08–13.95 ka b2k) and GI-1c (13.95–13.31 ka b2k), characterized by the first significant temperature increase after the Last Glacial Maximum.

This chronological assessment highlights a lack of collapses between the end of the Late Glacial Interstadial and the historical times, suggesting slope stability during almost the entire Holocene and increased activity during the Little Ice Age.

Understanding the timing of rock slope failure collapses during paraglacial crisis helps to define future scenarios of slope collapse under a changing climate.

Late Pleistocene to Holocene glacial, periglacial and paraglacial geomorphology of the upper Río Limarí basin (30-31 ºS) in the Andes of central Chile.

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The Andes of central Chile are a suitable region for assessing the geomorphic response of the mountain cryosphere to climate forcing. Despite this, detailed mapping of geo-cryoforms and last glaciation reconstructions in this region remain unresolved with few studies to date. Moreover, the region includes present-day different types of glaciers, with or without debris cover, as well as rock glaciers, suitably for studying present-day ice change in light of the paleo-glacier record. In this context, this research's purpose is to reconstruct the geomorphic imprint of the last glaciation and subsequent deglaciation in the Andean mountains of the Limarí basin, semiarid central Chile. For this, geomorphological maps of four formerly glaciated valleys in the head of two sub-basins of the Andean Limarí basin, namely Combarbalá and Río Hurtado, were built.

Field observations and the analysis of aerial photograph and satellite images allowed us to identify a mosaic of glacial, periglacial, and paraglacial landforms. Glacial landforms include a massive dead-ice moraine complex, with sinkholes and debris-filled stripes indicating former ice-cored moraine degradation, as well as landforms related to active ice processes such as glacial lineations and moraine ridges containing striated and faceted boulders. Current periglacial landforms such as rock glaciers, gelifluction tali, and protalus lobes occur in cirques and U-shaped valleys. Paraglacial processes are indicated by talus accumulation.

We suggest that glaciers, mostly without debris cover, expanded during the last glaciation in the upper Limarí basin. During deglaciation they would have been covered with debris in response to negative mass balance, evolving eventually to dead-ice moraines and extensive hummocky terrain at the end of the last glaciation. Moraine ridges and fluting punctuating the dead-ice moraine implies that the overall deglaciation process would have been interrupted by several glacial or post-glacial re-advances. Inactive rock glacier morphology converging with dead-ice moraines is evidence for the discussion of a potential evolution of the debris-covered glacier into a valley rock glacier. The transition from glacial to nonglacial environment has left detrital niches that behave as hosts for periglacial features such as cirque rock glaciers, gelifluction tali, and protalus lobes, which are responding to current climate changes.

Submarine glacial landforms in the southern part of the Baltic Sea Basin

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During the last glacial cycle, the Scandinavian Ice Sheet (SIS) was one of the Northern Hemisphere's largest ice sheets. The ice flow pattern of the last SIS was characterized by the occurrence of ice streams (corridors of fast-flowing ice). The Baltic Sea Basin hosted the Baltic Ice Stream complex, which was one of the main corridors of fast flowing ice within the SIS. This research offers a reconstruction of the last SIS dynamics in the southern part of the Baltic Sea Basin based mainly on the remote surveying of the seafloor relief and mapping glacial landforms.

Unravelling the puzzle of glacial processes operating within one of the most important palaeo-ice streams at the southern SIS sector will contribute to better understanding the dynamics of the entire ice sheet. The geomorphic signatures of the last SIS in the southern part of the Baltic Sea Basin are still poorly known and have not been analysed in detail so far. Until recently, the dynamics of the Baltic Ice Stream complex were mainly constrained by terrestrial observations. This research focuses on mapping submarine glacial landforms occurring on the southern Baltic seafloor. Our poster presents some relic glacial landforms delineated based on high-resolution multibeam swath bathymetry. We used grids of various resolution (from 0.5 to 5 m) interpolated from bathymetric data obtained from Hydrographic Office of the Polish Navy, RWE company and the Swedish Maritime Administration. Detailed mapping of submarine glacial geomorphology and GIS analyses of landform distribution enables us to decipher glacial processes associated with the Baltic Ice Stream complex and reconstruct the pattern of ice flow and margin positions in the southern Baltic Sea Basin.

Retreat of the Laurentide Ice Sheet margin in easternmost Québec-Labrador revealed by cosmogenic nuclide exposure dating

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The Laurentide Ice Sheet was the largest ice sheet of the Northern Hemisphere during the last glacial cycle. The effects of its demise on global climate and sea level changes during the subsequent deglaciation are unequivocal. Understanding the interplay between ice sheets and long-term or shorter-term (e.g., abrupt) climatic events is therefore critical for assessing the contribution of melting ice masses to past and future sea level rise. Here, we present new cosmogenic nuclide surface exposure ages from easternmost Québec-Labrador that allow refining the regional deglaciation history. This chronological dataset reveal that the Laurentide Ice Sheet disconnected from the Newfoundland Ice Cap at ~14.1 ka. Additionally, samples collected from moraine boulders document the occurrence of five major stillstands and/or readvance stages of the Laurentide Ice Sheet margin at ~12.9 ka, ~11.5 ka, ~10.4 ka, ~9.3 ka and ~8.4-8.2 ka. Our results highlight a strong sensitivity of the LIS to temperature changes in the Northern Hemisphere, as the documented continental ice margin stabilizations coincide with abrupt cooling events recorded in Greenland ice cores. Furthermore, they support the idea of a negative feedback mechanism induced by meltwater forcings into the North Atlantic Ocean which, in turn, provoked repeated cold reversals during the Younger Dryas and early Holocene.

Reconstructing glacial retreat in southernmost Patagonia since the last glacial maximum

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During the Last Glacial Maximum (LGM), a major outlet glacier of the Cordillera Darwin in southernmost Patagonia extended ~200 km through Canal Whiteside and into the large marine embayment Bahía Inútil. A suite of glacial landforms has previously been mapped and dated recording a series of re-advances shortly after the onset of deglaciation. Glacial retreat through Canal Whiteside is thought to have occurred between approximately 18-16 ka, but the exact timing and rate of retreat is poorly constrained. Marine geophysical data have suggested ice retreat occurred in stages, with the initial deglaciation of Bahía Inútil being slow, but accelerating as the ice retreated into deeper water in the northern part of Canal Whiteside. Stabilisation of the ice margin at a topographic constriction near Punta Yartou has been inferred based on the deposition of thick ice-proximal sediments in the strait, but the timing of this stabilisation was unknown. Here, we present new evidence from terrestrial cosmogenic nuclide dates from moraines on the eastern shore of Canal Whiteside near Punta Yartou. These moraines are nearly 70 km beyond modern ice limits in the Cordillera Darwin, and a similar distance from the LGM moraines in Bahía Inútil. The moraines mark the last known ice extent in Canal Whiteside before deglaciation in the fjords. We use these data along with published marine sediment cores and terrestrial radiocarbon dates from the fjords close to the current ice extent to constrain both the timing and rate of deglaciation in the region. We consider the role of climate, topography, and ice-loss through calving in driving this pattern of retreat. Our overall aim is to build an understanding of the rate of deglaciation and to understand how the ice sheet in this sector responded to Late Glacial and Holocene climate.

Early Pleistocene Glaciation records in cave sediments: insights from the French western Alps

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In the French western Alps, pre-LGM glaciations are little known in terms of chronology, spatial extent and dynamics because their reconstruction is strongly limited by the poor preservation of sedimentary archives in a context of strong relief rejuvenation, especially in the internal reliefs. Thus, although the last glacial periods, as well as the post-LGM glacial retreat phases, have been extensively reconstructed based on surface geomorphological and sedimentological records, we are severely lacking on information about Early to Middle Pleistocene glaciations in the western Alps.

(Paleo-)glaciers have not only left morphologies and deposits in the landscape. Pre-existing endokarstic networks can be used by glacio-nival melt water flows. Thus, fluvio-glacial sediments may be preserved inside cave systems. While surface glacial records are mostly eroded over a glacial-interglacial cycle (100 ka) or by subsequent glacial advances, the potential for preservation is much better in endokarstic systems where sediments can be stored over long term. In addition, several glacial occurrences might be preserved in endokarstic networks, providing chronological archives over multiple glaciations.

For this study, we investigated two caves in the French western Alps: Vallier (1520m, Vercors massif) and Chevalier (1670m, Chartreuse massif). Due to their peripheral locations and high elevations, these endokarstic systems were not influenced by last glacial extensions (MIS2/MIS4, possibly MIS6) but present fluvio-glacial sediment deposits attributed to early-middle Pleistocene glaciations. We collected allochthonous sediments inside these caves, combined with speleothem sampling, and performed multi-method sedimentological and geochronological analysis (cosmogenic isotope burial and paleomagnetic dating on detrital sediments and U-series dating on calcite concretions). Our aim is to place chronological constraints, as well as provenance information, on these ancient fluvio-glacial deposits, with the objective of reconstructing the paleo-extent/thickness and ice fluxes of Early to Middle Pleistocene glaciations in the French western Alps.

The sensitivity of the mountain cryosphere

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The presence of snow and ice is a distinctive characteristic of mid-latitude mountains worldwide. Under climate change, both through the late Quaternary and in the Anthropocene, the changing cryosphere exerts a strong influence on the dynamics of mountain systems. This includes their heat balance, regional climate and micro-climate, geomorphology, ecosystems and different types of human activity. However, the 'sensitivity' of the mountain cryosphere has been defined and interpreted in different ways in terms of key cryospheric properties such as mass balance and albedo. This means that the concept of cryospheric sensitivity is both ambiguous and multifaceted. In addition, mountain snow and ice have different distributions and dynamical controls and this suggests that any differential responses to climate forcing should result in changes to the snow/ice systems themselves as well as any downstream impacts on the land surface. This study examines the nature of the different sensitivities of the mountain cryosphere from both theoretical and field-based perspectives. Results show that snow and mountain glaciers have different sensitivities to radiative forcings that are linked to the surface properties of snow and ice bodies themselves. These sensitivities are strongly influenced by land surface feedbacks that are far more significant a control on cryospheric dynamics than equivalent feedbacks are for other elements of mountain systems. Thus, the cryosphere exerts a disproportionate control on the dynamics of mountain systems as a whole. Changes in snow and ice properties over time and space, across complex mountain topographies, give rise to temporal and spatial variations in sensitivity that show a nonlinear relationship to forcing. These feedbacks and outcomes of climate forcing are also not well parameterized through radiative models or regional-scale field observations. However, the sensitivity of the mountain cryosphere is critical in prediction of related slope hazards (in particular associated with deglacierization), meltwater yield into surrounding rivers, and sustainability of mountain landscapes, ecosystems and human activity.

Numerical modelling of subglacial ribs, drumlins, herringbones, and mega-scale glacial lineations reveals their developmental trajectories and transitions

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Initially a matter of intellectual curiosity, but now important for understanding ice sheet dynamics, the formation of subglacial bedforms has been a subject of scientific enquiry for over a century. Here, we use a numerical model of the coupled flow of ice, water, and subglacial sediment to explore the formation of subglacial ribs (i.e. ribbed moraine), drumlins and mega-scale glacial lineations (MSGL). The model produces instabilities at the ice-bed interface, which result in landforms resembling subglacial ribs and drumlins. We find that a behavioural trajectory is present. Initially subglacial ribs form, which can either develop into fields of organised drumlins, or herringbone-type structures misaligned with ice flow. We present potential examples of these misaligned bedforms in deglaciated landscapes, the presence of which means caution should be taken when interpreting cross-cutting bedforms. Under constant ice flow parameters, MSGL are absent from our experiments. However, drumlin fields can elongate into MSGL in our model if low ice-bed coupling conditions are imposed. The conditions under which drumlins elongate into MSGL are analogous to those found beneath contemporary ice streams, providing the first mechanism, rather than just an association, for linking MSGL with ice stream flow. Therefore, we suggest that the instability of subglacial bedforming explains the fundamental mechanics that lead to the initiation and growth of these landforms, solving the longstanding problem of subglacial bedform generation.

Evolution of sediment-landform assemblages at a recently deglaciated terrain: The case of the Grey glacier in southern Patagonia

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Patagonian glaciers have been retreating rapidly during the past decades leaving behind a suite of sediment-landform assemblages that reflect the response of the cryosphere to severe warming episodes in addition to non-climatic factors, such as topography and/or the existence of proglacial lakes. Combining remote sensing techniques, geomorphological mapping, sedimentary analysis and Schmidt hammer measurements, we assess glacier-landscape dynamics, including debris transport paths, deposition environments characteristics and weathering rates of the Grey glacier in southern Patagonia (~51° S). Our aim is to outline a detailed morphosedimentary model for a temperate glacier to further understand processes involved in glacier withdrawal and to provide a modern analog to improve paleoclimate reconstructions based on glacial geology. Our preliminary results indicate that the ice receded ~1.6 km from the innermost moraine to its present-day position since at least 1974. We identify a suite of sedimentary-landforms assemblages which indicate that the glacier terminus transitioned from terrestrial to lacustrine environments in past decades, such as subaerial and subaqueous moraines, shorelines and terraces. We hypothesized that dominant lithofacies varies from angular-to-subangular bouldery gravel tills in ice marginal features to angular gravels in supraglacial deposits and subrounded-to-rounded sandy gravel units in glaciolacustrine landforms. We expect that Schmidt hammer measurements on recently deglaciated bedrock outcrops will reveal a decreasing surface weathering transect from distal moraines to present-day ice front showing a potential correlation with external controlling factors. Our results will inform us about the coupled influence of climate variations and proglacial environments in glacier recession rates and, especially, how proglacial lakes might enhance climate-driven ice withdrawal, yielding key insights for better understanding the response of tidewater glaciers to the ongoing climate change and offering empirical constrains for past glacier behavior and paleoclimate modelling.

Post-Little Ice Age Glacial Geomorphology of Contrasting Topographic Settings at Skálafellsjökull, Southeast Iceland.

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Iceland's glaciers are known to be particularly sensitive to changes in climate and are heavily influenced by changes in atmospheric and ocean circulation in the North Atlantic, causing changes in glacier mass balance. Iceland lies at the boundary between major ocean currents, with changes in these currents impacting Icelandic climate throughout the Holocene. Glacier retreat is also influenced by several other factors including underlying topography, glacier hypsometry and geology, which impacts glacier response times to changes in climate. Understanding these changes in glacier response times is important for modelling changes such as future sea level rise and water availability.

Southeast Iceland has been the focus of numerous studies on glacier retreat since the Little Ice Age (LIA) (ca. 1250-1900 AD), however there has been less focus on glacier dynamics and topographic influence. Skálafellsjökull is an outlet glacier of the Vatnajökull ice cap in southeast Iceland that has been retreating since the LIA maximum (~1890). This glacier presents a topographically diverse mountainside, influenced by underlying geology, offering an opportunity to explore the relationship between glacier behaviour and underlying topography in an environment with the same climatic influence.

Here we present high resolution mapping of glacial landforms, using high resolution aerial orthophotos and digital elevation models, collected using an Uncrewed Aerial Vehicle (UAV). The landforms mapped are typical for southeast Icelandic temperate glaciers, comprising composite and recessional push moraines, sawtooth moraines, and associated fluting. The UAV-captured imagery shows three distinct topographic settings that each have a distinctive geomorphological signature. This new geomorphological mapping at Skálafellsjökull will be useful for understanding patterns and rates of retreat at Skálafellsjökull, and glacier response to varied underlying topography.

Exploring landform expressions of subglacial thermal regime in marine and terrestrial continental ice sheet settings

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Detailed geomorphological records of deglaciated continental margins are increasingly widespread, with their interpretation providing important insights into the flow and retreat behaviour of past and present ice sheets. This adds to the long tradition of glacial geomorphological scrutiny of deglaciated terrestrial areas. Based on such work, it has been possible to determine suites of landforms, and landform characteristics, that are indicative of particular formative glaciological environments and ice flow and/or retreat regimes. However, it has often been the case that such models for interpretative 'inversion' of the landform record have considered the marine and terrestrial domains in isolation and the fundamental applicability of interpretative models across the whole ice sheet bed is challenging to establish, and rarely tested.

Basal thermal regime - and, by extension, basal hydrology - is fundamental to how ice flows across its bed, and fundamental to landforming processes and landform preservation. Cold-based and warm-based basal conditions are known to vary beneath ice sheets, yet detailed knowledge of how such regimes interact and how they vary across space and time is limited, particularly so over the scales and life cycle of a continental ice sheet. Importantly, how a terrestrial- or marine-based setting influences thermal regime, and its manifestation in the landform record, is rarely considered. Using examples from the marine and terrestrial sectors of former Northern and Southern hemisphere ice sheets, we explore landform expressions of subglacial thermal regime. We ask to what degree differences in landforms associated with end-member subglacial thermal states of cold-based ice and channelised meltwater reflect contrasting glaciological processes governing ice flow and retreat in marine and terrestrial settings, and/or reflect sedimentological processes of landform construction in these different domains. With such insights, we hope to refine approaches to inverting the preserved glacial landform record for interpretation of subglacial thermal regime.

Channel geometries formed by meltwater turbidites across the last glaciation on the North Sea Fan

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Meltwater discharge is an important process associated with retreating ice streams. We use the North Sea Fan to study the geometries of meltwater-turbidite channels formed during the last glacial highstand (23 – 19 ka). High-quality 3D seismic reflection data (vertical resolution of 2 m and bin size of 6.25 x 18.75 m) covering 14000 km^2 is used to map six surfaces, and subsequent seismo-geomorphological analysis allows for the delimitation of five units with different seismic facies. A roughness index is calculated using cross-sections along the mapped surfaces. Width and depth measurements are taken along twelve points in different channels at different stratigraphic levels.

Results show channel width varying from 100 m to >2 km, with channel depths reaching up to 105 meters. Channels exceed 100 km in length and have extremely low sinuosity, with maximum values of 1,05. Channel slope angles show small variations, ranging from 0.01º to 0.014º. Different roughness trends are recorded for units dominated by down-slope processes compared to those dominated by bottom currents and settling from suspension. Our interpretations suggest that units dominated by turbidity currents and debris flows have a distinguishably rougher surface. In contrast, results reveal poor correlation between depth, width and length measured, within a single horizon and across horizons.

The low-sinuosity meltwater-fed channels have dimensions varying from meter to kilometric scales, representing energy fluctuations of the flows that eroded into the paleo-seafloor. The high channel-property variability is compatible with a high-mobility system, where the channels are short-lived and easily affected by subsequent events during a 4000 years period. These new insights demonstrate the variability of predominant active processes, such as settling of the suspension load, turbidity and cohesive flows, during a period of extreme sedimentation on the North Sea Fan. These downslope processes significantly contribute to the formation of this glacial fan during the last glacial-interglacial cycle.

The deglaciation of Ésera Valley (Central Pyrenees, Spain): past evolution, current situation and future perspectives.

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The local Last Glacial Maximum in the central Pyrenees was reached 60,000 years ago, since then, deglaciation has included periods of stabilization and glacier re-advance. The scarcity of well-dated glacier landforms prevents assessing precisely the timing of the deglaciation stages and identify the response of past glaciers to known rapid climate changes. In this contribution we present Pllan d'Están lacustrine record in the Ésera Valley spanning the last 45,000 years of climate and environmental change. A combination of sedimentological, geochemical, pollen and diatom data from a 4.4 m long core, and age models based on radiocarbon in the lake sequence and cosmogenic dating from moraine deposits, allowed defining paleoenvironmental stages. The onset of the lake sequence is a carbonate-rich unit without organic matter, interpreted as a proglacial lake lasting from 45 to 34 ka. From 34 ka to 11.7 ka, the sediment is characterized by the alternation of dark and light laminae, suggesting more intense runoff processes. The first part of this period (34-14 ka) is dominated by steppe herbaceous pollen (mainly *Artemisia*) indicative of a cold scenario with the glacier nearby. After 14 ka the development of arboreal vegetation with the regional typical *Juniperus-Betula-Corylus* succession indicates a temperature increase, although with still arid conditions. Furthermore, changes in diatoms assemblages and the higher content of organic matter point to a limited glacier influence during this this second stage (14-11.7 ka). During the Holocene, the content of organic matter increased, and a peatbog was developed during the mid Holocene, as both diatoms and hydro-hygrophytes pollen assemblages indicate. Late Holocene sediments are badly-preserved, but glacier evolution was studied by combining geomorphological mapping and high spatial resolution satellite imagery. Since the end of the Little Ice Age, Pyrenean glaciers retreated to the cirques and their surface shrunk from 2,060 to 232 ha from years 1850-2020. In the Ésera Valley, the Aneto Glacier, the largest one in the Pyrenees, has decreased a 64.7% in surface and 30.5 m in thickness in the last 41 years. Considering the current remaining maximum ice thickness (11.8 m), we expect it to disappear in the following decades.

Reconstructing the evolution of a post-Little Ice Age deglaciated alpine valley through the DEM of Difference technique

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Since the termination of the Little Ice Age (LIA, ca. 1830), the accelerated glaciers' shrinkage along mid-latitude high mountain areas promoted a quick readjustment of geomorphological processes. For that reason, proglacial areas are among the most sensitive Earth's landscapes to climate change. The latest deglaciation is still on-going and it is affecting large areas; one of the main result is the onset of fresh geomorphological processes (paraglacial dynamic) and the accelerated rate of evolution of freshly exposed surfaces. A potential useful remote-sensing method for investigating such dynamic areas is the DEM (Digital Elevation Model) of Difference techniques (DoD), which quantify volumetric changes of a territory between successive topographic surveys. We applied this method, coupled with a detailed geomorphological analysis and comparison with historical maps, for reconstructing post-LIA deglaciation dynamic and the onset of fresh paraglacial processes along the Martello Valley (Stelvio National Park, Central Italian Alps). The head of the Martello Valley is still glacierized with three main ice bodies resulting from the huge shrinkage of the single glacier active at the apogee of the LIA. Aftermath glaciers lost the 60% of the initial surface area and consequently largely modifying the landscape and expanding the surface of the proglacial areas. The DoD analysis of 2006-2015 timeframe highlights deep surface elevation changes ranging from +38m along the foot of rock walls, where gravitative processes are more active, and -47m where the melting of buried ice caused collapses of the proglacial surface. This approach permits estimating the volume of sediments mobilized and reworked by paraglacial processes. Here, in less than 10 years, ca. 23675 m^3 of sediment were removed along the proglacial area and transported down valley. This highlights the dynamicity of proglacial areas and the relevance of paraglacial processes today as much as during past phases of deglaciation.

Controls on late Holocene and 20th century ice shelf dynamics in northeast Greenland.

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Over the past three decades satellite observations over Greenland have revealed that marine terminating glaciers and ice shelves have been thinning at an accelerating rate in response to both increased air and ocean temperatures. Beginning in the early 2000s, the ice shelves that front the Northeast Greenland ice stream (NEGIS) (Zachariae Isstrom and 79N) have started to destabilise, causing great concern for the future stability of the Greenland ice sheet. This project will explore the Late Holocene and twentieth century evolution of the 79N ice shelf, which currently buttresses the NEGIS. The NEGIS drains the northeast sector of the Greenland ice Sheet (GrIS) and contains approximately 1.2 m sea-level equivalent. Its future stability is pivotal not only to future mass balance of the GrIS but also the freshwater flux to the northeast Atlantic and specifically, to the North Atlantic Deep Water overturning circulation. This project will focus on the late Holocene to 21st century sedimentary history of Blaso, an epishelf lake to the north of the 79N ice shelf. Lake sediment cores will be analysed using a multiproxy approach in order to establish an characterise the Late Holocene sedimentation processes and patterns. This characterisation will then be utilised to frame 20th to 21st century sedimentary changes in the lake, with an emphasis on changes over the last 20 years. This recent understanding will be key to determining the future of the 79N ice shelf and, critically, will aid in identifying recent ice shelf thinning and the first signs of contemporary breakup in response to both ocean warming (Atlantic Water ingress) and air temperature increase (increased freshwater flux). Gaining an understanding ice stream responses to climate from the little ice age to present, will enable scientists to better understand how 79N will respond to near future climate change.

Geomorphological record of a former ice stream to ice shelf lateral transition zone in Northeast Greenland

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Understanding ice stream dynamics over decadal to millennial timescales is crucial for improving numerical model projections of ice sheet behaviour and future ice loss. In marine-terminating settings, ice shelves play a critical role in controlling ice-stream grounding line stability and ice flux to the ocean, but few studies have investigated the terrestrial geomorphological imprint of ice shelves during deglaciation. Here, we document the terrestrial deglacial landsystem of Nioghalvfjerdsfjorden Glacier (79N) in Northeast Greenland following the Last Glacial Maximum, and the lateral transition of that margin to a floating ice shelf. High-elevation areas are influenced by local ice caps and display autochthonous to allochthonous blockfields that mark the interaction of local ice caps with the ice stream below. A thermal transition from cold- to warm-based ice is denoted by the emplacement of erratics onto allochthonous blockfields. Below ~600 m a.s.l. glacially abraded bedrock surfaces and assemblages of lateral moraines, 'hummocky' moraine, fluted terrain, and ice-contact deltas record the former presence of warm-based ice and thinning of the grounded ice stream margin through time. In the outer fjord a range of landforms such as ice shelf moraines, dead-ice topography, and weakly developed ice marginal glaciofluvial outwash was produced by an ice shelf during deglaciation. Along the mid- and inner-fjord areas this ice shelf signal is absent, suggesting ice shelf disintegration prior to grounding line retreat under tidewater conditions. However, below the marine limit, the geomorphological record along the fjord indicates the expansion of the 79N ice shelf during the Neoglacial, which culminated in the Little Ice Age. This has been followed by 20th Century recession, with the development of a suite of compressional ice shelf moraines, ice-marginal fluvioglacial corridors, kame terraces, dead-ice terrain, and crevasse infill ridges. These mark rapid ice shelf thinning and typify the present-day ice shelf landsystem in a warming climate.

The transition from glacial to interstadial in the lithosedimentary and pollen records from Balbieriškis outcrop, Late Weichelian Glaciation in South Lithuania

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Investigations of the Late Weichselian sequences in the Baltic region are of great importance for the determination of the extent of the Late Weichselian glaciation and for the evaluation of transition from glacial to interstadial. Lithosedimentary and paleobotanical studies of the deposits of the Late Weichselian glaciation in the midstream of the Nemunas River were performed. The paleogeographical and paleoclimatic conditions during the formation of intertill sediments in the Balbieriškis outcrop in Southern Lithuania were evaluated. The structure of these deposits analysed and studies of tills were carried out which allowed us to determine the paleogeographical conditions of their formation. Spores, pollen, and other microfauna (microflora) findings in intertill sediments were analysed and paleogeographical and paleoclimatic conditions of their sedimentation were evaluated.

The sequence of the Balbieriškis outcrop reflects the presence of nonglacial palaeoenvironments during the deglaciation of Late Weichselian ice. Two tills of the last glaciation, which differ significantly in their composition and glacier movement paths, and the relatively continuous sedimentation process indicating intertill sediments separating them, testify to global climate changes in the late ice age and to the restructuring of glacial lobes of deglaciation in the southeastern part of the ice sheet. These can be named as phenomena of the rank of a significant stage of deglaciation. Research of the intertill sediments testifies about the existence of climatic fluctuations which are reflected in both pollen and spores, and lithostratigraphic records. A discontinuous sedimentation and vegetation composition witness to an open landscape of steppe-tundra, scattered wooded areas vegetation, and the emergence of thermophilic vegetation afterward, which could point to increased annual temperature and higher humidity.

In Lithuania, the Late Weichselian Glaciation is referred to as the Late Nemunas Glaciation (Upper Nemunas Formation). The available material allows us to legitimize the Balbieriškis interstage period in the Late Nemunas Ice Age between the Grūda and Baltija stages (Grūda and Baltija sub-subformations) in the regional Quaternary stratigraphic scheme.

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New Younger Dryas evidence of glaciers advances in the upper valleys of Făgăraș Massif (Romania) via 10Be exposure dating

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Past glaciations extent and chronology in the Southern Carpathians have been the subject of a disputed debate during most of the 20th century. The Romanian Carpathians finally benefitted in the last two decades from several studies presenting numerical age datings of the glacial deposits and erosion surfaces that improved considerably the knowledge on the last glaciations chronology. Despite the fact that Făgăraș Massif is the highest massif from Southern Carpathians (and of the Romania) and the richest in terms of glacial features, with deep glacial valleys and large cirques, it has remained less studied and dated in relation with the Pleistocene glaciations.

New exposure ages based on in situ produced ^{10}Be, ranging from Bølling-Allerød to Younger Dryas and Early Holocene are in good agreement with the recent European records, displaying the complete ice melting during Bølling-Allerød warm phase, one possible glacial advance during the Older Dryas (around 13.6 ka), glacial reformation and advance during the Younger Dryas and possible Early Holocene advances related to Pre-Boreal Oscillation when cool and humid conditions have been present over Europe. Based on the morphology of the glacial cirques which hosted Younger Dryas glaciers (proven by numerical ages) we performed a morphometric analysis for all the glacial cirques and finally we model the presence of Younger Dryas glaciers in the whole massif.

Samples were chemically processed at LN2C at CEREGE, France and at RoAMS Laboratory - IFIN HH, Romania. Targets of purified BeO were prepared for AMS measurements and measured at *ASTER, the French National AMS Facility* (CEREGE, Aix en Provence).

Loess generation in western Ireland during the last glacial termination and implications for postglacial climate

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We present the first quantitative analysis of loess to be recorded in Ireland. Located on Ireland's Atlantic coast, the Burren forms a classic upland glaciokarst characterised by extensive limestone pavement and ice-plucked escarpments. The origin and nature of a quartz-dominated sediment found here–and its relationship with climatic conditions in the broader North Atlantic–has remained obscure, although it is widely accepted that the Burren supported an extensive mineral soil cover until the Mid Holocene. Uncertainty around the timing of Late Quaternary deglaciation, and thus the window of opportunity for silt entrainment and deposition, has further compounded our understanding of this unusual sedimentary unit.

To address persistent questions surrounding the genesis of the Burren silts, and climatic implications of cold-climate aeolian sediments for Europe's Atlantic margin, we first established the timing of deglaciation (with beryllium-10) to Heinrich Stadial 1. We then applied a coupled sedimentologic-geochemical approach to deposits at 11 sites throughout the Burren, several of which reveal an intricate stratigraphic relationship with varved sediments and relict periglacial features. Grain-size analysis depicts a consistent modal size, with most samples classified as clayey-silt/silty-clay, while SEM imaging reveals predominantly angular grain morphologies and conchoidal fracturing. XRF indicates the silt chemistry is consistent regionally and with similar deposits in the UK and France previously identified as loess. Meanwhile, age profiling of zircons identifies the primary source as the Carboniferous Clare Basin (SW of the Burren), with secondary input from Devonian lithologies immediately to the east. Both sources suggest a highly localised origin for the Burren loess, rather than more distal transport of Eurasian loess.

At multiple locations, we observed a simple bi-fold stratigraphy, whereby the lower clay-rich unit is overlain by a coarser unit also containing ^{14}C-datable charcoal. By our working hypothesis, the lower unit represents the original *in situ* loess deposited immediately after deglaciation and under environmental conditions conducive to aeolian dust transport; the upper unit corresponds to subsequent remobilisation and redeposition during the mid-Holocene, potentially reflecting climatic and/or anthropogenic agents. Initial anisotropy of magnetic susceptibility data support this hypothesis, while ongoing OSL dating will afford direct dating of both loessic units.

Investigating the interactions between the Jura ice cap and the Rhone glacier using exogenetic cave sediments and glaciotectonized surface deposits

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The Jura Mountains are home to many karstic features that can trap and retain sediments. These exogenetic deposits are an important archive for paleoenvironmental information due to their ability to preserve sediments that have otherwise been eroded or reworked on the surface. To better understand the spatiotemporal evolution of the Rhone glacier across the Alpine foreland and its interaction with the Jura ice cap, a sedimentological study and field investigation were made in the Orbe and Jougnena valleys and along the Petit Risoux in the central Jura. In this study, exogenetic cave sediments of Alpine origin from Grotte aux Fées were investigated using isochron-burial and simple burial dating techniques with cosmogenic ^{10}Be and ^{26}Al. While Alpine clasts were also found in other caves, the Grotte aux Fées was chosen for dating because it lies beyond the previously identified maximum extent of the Alpine ice sheet during the Last Glacial Maximum (LGM) as well as Middle Pleistocene glaciations. To better understand the context of the exogenetic sediments, a field investigation of surface features was conducted. Observations included variations in till composition, morphologic features, and proglacial deposits. Laminated glaciolacustrine sediments up to 50 meters thick are found in the Orbe and Jougnena Valleys and were deposited in glacially dammed lakes. When outcropping on the surface, these glaciolacustrine deposits often appear glaciotectonized. The glaciotectonism has recorded varying senses of shear, indicating advances from both the Jura ice cap and Rhone glacier and providing new information for understanding the dynamic interactions of glaciers competing for space on the southeastern valleys of the Jura.

Small drumlins melting out from underneath retreating glaciers – an under-used archive of recent glacier change?

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Most glaciers world-wide have been retreating for the last few years to decades. Due to atmospheric amplification effects, this change is most pronounced in high-mountain regions such as the European Alps and in the Arctic. One side-effect of this retreat is the observable de-icing of glacier forelands. We have witnessed and recorded the melting-out of new landforms that had hitherto been hidden from view underneath the ice in several locations. These landforms often include small and transient flutes, subglacial channels, small eskers, but also larger streamlined landforms, including drumlins, which are perhaps among the most enigmatic landforms produced by glaciers.
We here present detailed field observations and measurements from small drumlins in two very different glacier systems. Hornkees, Austria, is a small temperate valley glacier in the Eastern Alps that flows mostly over bedrock. Storglaciären on the other hand is a polythermal valley glacier of comparable size in Arctic Sweden that flows over a patchwork bed of bedrock and soft sediments. Using structural measurements of fractures and fissures, in-situ soil penetrometer measurements and laboratory data of water content, grain size and shear strength, we aim to shed some light on the influence of spatial and temporal variability on sediment properties. Equally, comparing these findings to former glacier dynamics enables us to establish clear genetic links between ice dynamics and landforms imprint. These links are extremely valuable for reconstructions of former ice dynamics displayed, for example, by the last ice sheets, including the Scandinavian Ice Sheet, during multiple glaciations during the Pleistocene.

A new ice sheet reconstruction method and its application to the land terminating sector of the Scandinavian Ice Sheet

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The landform record provides a spatially-continuous and data rich opportunity for evaluating the evolution and dynamics of ice sheets. Developments in both chronological tools and the wide-spread availability of high-resolution Digital elevation models have called into question long-established ice margins of the Scandinavian Ice Sheet (SIS). Developing an ice sheet scale reconstruction is required to probe controls on dynamics, yet is difficult to do by synthesizing local studies. This is in part because assessing, comparing and evaluating evidence from regional studies can be difficult with differing regional observations and resulting in regional reconstructions often being irreconcilable. We have developed a landform-driven reconstruction method that can be applied at the ice sheet scale. We demonstrate the method with its application to the land terminating sectors of the SIS. Selective symbolic landform mapping off variable resolution DEMs of moraines, outwash fans, tunnel valleys, lineations forms the basis for reconstructing margin retreat patterns and geometries. Iterative retreat pattern reconstructions in sub regions are ultimately linked to from a broader regional pattern of ice dynamics. In domains where simple monotonic retreat patterns are unable to satisfy the symbolized landform record we show how numerous reoccupations of ice in the last glacial or previous glacial cycles can explain the preserved record. We further expand on ways transgressive ice marginal features such as meltwater channels and moraine belts can be assessed in a reconstruction. An ice margin reconstruction of the entire land terminating sector (~1.2million Km^2) of the SIS generated by our method is presented. We expect this reconstruction can serves as a useful empirical data set for the ice sheet modeling community as well as provide a contextualizing framework for crucial regional studies.

Chronology of patagonian deglaciation and Late Pleistocene Atlantic-to-Pacific drainage reversal of palaeolake

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We present a study on the glacial and paraglacial geomorphology of a Patagonian Cordillera Valley that is key to understanding evolution of the great lakes of Patagonia. 10Be cosmogenic nuclide exposure ages of ice-moulded surfaces from the Bayo River Valley confirm that the valley became ice-free before 13.4 - 14.2 ka. This valley constituted the first outlet of the Chelenko Lake, precursor of the General Carrera–Buenos Aires Lake (GCBAL), toward the Pacific Ocean. This age constrains the timing of the lake drainage reversal from the Atlantic Ocean to the Pacific Ocean. Alluvial fans and terrace levels recognized in the eastern segment of the valley at the same altitude as terrace levels observed in the GCBAL basin confirm that the Bayo Pass controlled the elevation of the lake once the drainage reversed to Pacific Ocean. 10Be cosmogenic nuclide exposure ages also confirm that the maximum advance of the Exploradores Glacier since its major retreat >13.4 - 14.2 ka ago occurred during the Little Ice Age, the last remnant of glacial drift in these valleys.

Chronology of glacial advances and deglaciation in the the southernmost Atacama Desert based on geomorphological mapping and cosmogenic 10Be exposure ages

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Glacier advances and deglaciation have left a geomorphic imprint that has recording sensible changes in moisture supply in the southernmost Atacama Desert. In this work, the glacial landforms of the Encierro River Valley (29.1°S-69.9°W, 5475 m asl) have been revisited and new detailed geomorphological mapping and 10Be exposure ages from moraine boulders and ice-molded bedrock surfaces is presented. We found that the former glaciers of El Encierro valley extended 16 km down valley (up to 3750 m asl) during the last local glacial maximums, when they built terminal moraine arcs in telescopic patterns (ENC 1a-d). These glaciers built five frontal moraine ridges, whose exposure ages in moraine boulders range between 26 and 33 Ka (ENC 1d) and 39 ka (ENC 1a). Exposure ages on lateral moraines and ice-molded bedrock surfaces were developed by recessional stages of the glacier during the retreat that occurred between 18-20 ka. Ten kilometers up valley from the ENC 1, the ENC2a-d moraine arcs correspond to small ice advance/still-stands by 17-18 ka. To explain the latter, the ice should have mostly disappeared fast in the main valley at 18 ka. Deglaciation may be related to the southward shift of the South-Westerly winds as reported in other paleoclimatic archives in Chile for this period.

Loamy mantle of East-European Plain: morphostratigraphy and facies architecture as a key to the Late Pleistocene regional correlations

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Periglacial areas of Weichselian ice sheets are long studied as a source of climatostratigraphic data correlatable with the global paleorecords and to understand the complex landscape response to changes in glacial dynamics. Pronounced loess-paleosol series majorly accumulated along the southern margins of the periglacial zone proved to be a reliable paleoarchive for such reconstructions. However, the closer periphery of past ice sheets still lacks a comparable paleorecord as the thickness of postglacial deposits declines northward against the growing intensity and dynamics of landscape transformations. A specific loamy mantle, which has remained a stumbling block for over a century-long scientific discussion, covers the interfluvial areas of central and northern parts of the East-European Plain. It can be regarded as a northern substitute of loess-paleosol series though of a rather more homogenous and less explicit structure that left its genetic and age interpretations quite inconsistent and controversial. Nevertheless, a detailed investigation of several uplands in the marginal zone of the Late Saalian glaciation allowed us to distinguish the facies architecture of cover loams. We elucidated the principal set and succession of characteristic lithostratigraphic units separated by a series of superimposed cryogenic and paleosol horizons, which eliminate the heterogenous origin and prolonged accumulation of the loamy mantle during the Late Pleistocene. Buried cryogenic deformations and paleosol features can be utilized both as stratigraphic markers and climate indicators when their position and replicability in paleolandscapes are considered. The lithological structure of each unit reflects a specific set of features indicating distinct changes in periglacial paleoenvironments that turn out to be either gradual or abrupt revealing several major erosion episodes during the Weichselian. That elaboration on the morphostratigraphy of cover loams was enabled due to a combined application of macro-, meso- and micromorphologic methods during both field and laboratory examination of 3D-organization of deposits supplemented by geomorphic analysis of modern and paleotopographies of interfluves. That provided a reliable basis for chronostratigraphic correlations throughout the entire Late Pleistocene periglacial zone showing a high potential of the hierarchical morphogenetic approach to unravel the depositional history of such clastic sedimentary covers often lacking a precise numerical age control.

Calderone glacieret, a unique archive for a possible paleoclimatic reconstruction of the Apennine region

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The ongoing global warming has relevant effects on the worldwide cryosphere. During the last decades, the more negative consequences have been on the most delicate snow and ice environments. Calderone ice body, classified as glaciaret split in two separated portions since the summer of 2000, is one of the most significant examples of the transition from glacial to periglacial environment due to climate change. Calderone is the southernmost remained ice body in Europe and represents a unique archive for the paleoclimatic reconstruction of the Apennine region. Indeed, despite the high summer temperature that occurred in the last decades, the ice body is still conserved thanks to the presence of debris cover that protects the ice under layers from solar radiation. In the frame of Ice Memory project, last May one 27.2 m down to the bedrock ice core was extracted in order to identify the ice layeringand to achieve chemical and biological information that characterize the surrounding area. To better indagate the evolution of Calderone since 1999, a comparison among different Ground-penetrating radar (GPR) and topographic surveys were carried out. Considering the rapid temperature increase of the last years, since 2015 annual photogrammetric surveys have been conducted in order to calculate the geodetic mass balance. In addition, before the drilling operation of last May, in March 2022 a high-resolution GPR survey associated with Electromagnetic (EM) and GPS measurements were achieved to better indagate the bedrock morphology, the glacier thickness, and the ice stratigraphy.

Here we present the results of the 2022 geophysical surveys, the comparison with former measurements, and the first stratigraphic information from the ice core. The first preliminary results show that despite the rapid climate change of the last twenty years, since 2000 the thickness and the extension of the two portions of Calderone glaciaret have not undergone significant changes. This represents an amazing and unique example in the Apennine region of ice conservation under the massive temperature increase. For this reason, the Calderone ice core will be one of the best opportunity for paleoclimatic and paleoenvironmental reconstructions of the surrounding Mediterranean area.

Coastal dune timing, migration and formation on K'gari (Fraser Island) through the Quaternary

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K'gari (Fraser Island) is the world's largest sand island and contains multiple sequences of parabolic and transgressive dunefields with aeolian sediments dating back to over 800 ka and surface dunes dating to at least 350 ka. This paper will discuss the role of antecedent topography, sediment supply and wind fields on dune morphology and extent. The earliest dunes date back to the Mid-Pleistocene Transition and all of the major dune units are associated with post-glacial marine transgressions. Over the southern two-thirds of the island, dunes relating to the MIS 7 high-stand dominate. For the Holocene, the largest and most extensive dunes are associated with the main post-glacial transgression and there are small dune sequences that relate to minor sea-level perturbations. This difference appears to be related to the relative scale of sediment supply associated with the events, with the main transgression driving significant sediment supply into the aeolian system. Dune formation varies along the K'gari coastline with steep ramparts in the southern part of the island limiting the inland migration of Holocene dunes. Where the rampart elevation is lower, more extensive Holocene dune fields, comprising both parabolic and transgressive dunes, have formed. The far northern part of the island is much lower elevation than the rest of K'gari and it is likely that this area was transgressed during a Late Quaternary high-stand, most likely MIS 5e. We conclude that terrestrial antecedent topography plays a key role in the modern form of the dune fields but that the limits of transgression are controlled by the magnitude and duration of the high sea-stands. Finally, we debunk a long-standing hypothesis that dunes on Kgari are related to aridity at the LGM.

Stratigraphy of the World’s Largest Coastal Sand System as Revealed by Ground Penetrating Radar, Great Sandy Coast, Queensland, Australia

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The south east Queensland (SEQ) dune fields in Australia, contain K’Gari (Fraser Island), the Cooloola Sand Mass, Yarun (Bribie Island), Mulgumpin (Moreton Island) and Minjerribah (North Stradbroke Island). This system is home to three of the world’s largest sand islands and the world’s longest continually active coastal dune field. Their sands originate from a >1100 km longshore drift current that moves sediment from south central New South Wales northward until it is redirected off the continental shelf at K’gari’s Sandy Cape. This system has been the focus of several decades of research to determine the timing of large-scale aeolian activity, and to elucidate the relationships between abiotic and biotic drivers of coastal/dune field evolution (i.e., climate, sea level, human activity).

A series of ground penetrating radar (GPR) surveys were conducted along the SEQ coastline between 2012 and 2019. The aim was to assist in developing a stratigraphic framework to link surface expression of dune forms and other features (i.e., lakes, wetlands, coastlines) to subsurface architecture, as well as assist in reconstruction the physical aspects of the environment and support coring for temporal control. The research has been focused on K’Gari and Cooloola but supporting data has been collected on Minjerribah and other areas.

The GPR outputs were analyzed using a facies-based perspective to identify the characteristics of the bounding surfaces and internal reflections. The data provide an interpretation base for the original depositional processes, post-depositional modifications, and anthropogenic activities. Four (4) major classes of facies were identified (interference, primary deposition, modified and anthropogenically altered) along with subclasses that relate to the specifics of the environment of deposition or style of modification.

This paper will show examples of GPR collected in active/modern environments and link with GPR data from other locations where features do not possess a surficial expression. Ultimately, a database of GPR facies for the aeolian environments of the south east coast of Queensland will be developed for use in understanding the spatial and temporal changes to the environment and assist in extracting valuable information on how the landscape has responded to past variations in climate.

Stratigraphy, chronology, and provenance of paleodune sediments in the Aconcagua and Rapel basins during the Late Pleistocene: Towards a model of paleodune formation in coastal central Chile

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The aeolian stratigraphic record on the coast of central Chile (32°-35°S) includes paleodune sequences separated by interstratified paleosols. Previous work has associated these sedimentary units with paleoclimatic changes linked to the oscillation and intensification of Southern Westerly Winds. Therefore, these eolian deposits are regarded as proxies of the paleoclimate of central Chile; nonetheless, detailed sedimentary analysis of these eolian records is lacking. The spatial distribution of the dune deposits (north of Andean river's mouth) suggests that the origin of the sands is related to former Andean to coastal glacial and/or fluvial processes. However, these processes have not been investigated in detail. Some unresolved questions are: When did coastal dunes in central Chile form? Which rocks provide the sediments that constitute the dunes? What role do Andean glaciations play in dune morphogenesis? What are the paleoenvironmental implications of the paleodune-paleosol sequences?

We present our methodological approach and results for the Aconcagua and Rapel basins, whose study sites include the paleodunes, dunes, fluvial terraces, and one moraine. At these sites, we collected detailed stratigraphic information, dated detrital zircons by LA-ICPMS (U-Pb in 100 grains per sample), and dated paleosols sands by ^{14}C and OSL. The latter is based on a pIRIR225 (post infrared, infrared stimulated luminescence @225°C) single aliquot regenerative (SAR) dose protocol for potassium-rich feldspar. This method has been successfully applied in previous studies and used to establish reliable chronologies for the aeolian sediment record of Central Chile. Our OSL results show that periods of dune accumulation and pedogenesis (interpreted to reflect wetter conditions) occur during MIS 4, 3, and 2. When comparing the U-Pb detrital zircon ages with the longitudinal geologic belts making up the Aconcagua and Rapel basins we identify different rock sources (e.g., Andean and Coastal). This is evidence of a restricted local basins provenance of sands that made up the paleodunes. The results suggest that main sources of sand change their relative importance through the last ice age (MIS 2 Andean-affinity; and MIS 4 Coastal-affinity). We discuss implication of our data towards a model of paleodune formation and their stratigraphic record in coastal central Chile.

The Southern westerly winds as recorded by the Chigualoco paleodune stratigraphic record in costal semiarid central Chile (31ºS) during the Late Pleistocene

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The southern westerly winds (SWW) are probably the most important climate element of the southern middle latitudes. Their position and intensity governed by low and high latitudes temperature gradients affects ocean and atmosphere dynamics in the southern middle latitudes and beyond. Thus, determining the past SWW changes through proxy records have far-reaching implications for a better understanding of the climate system at different temporal and spatial scales. The paleodune sedimentary records in the coast of central semiarid Chile have been proposed as proxy for reconstructing the SWW variability through the last glacial cycle. This remark is based on the existence of stratigraphic sequences exposing alternating paleodune and paleosol sedimentary couplet units linked to SWW latitudinal variability (Dune= south shifted SWW, dry conditions in central Chile; Paleosol= north shifted SWW, humid conditions). Nonetheless, to present only few paleodune records have been investigated and their paleoclimate signal is still to be better understood. Moreover, the factors controlling paleodune formation in the region remain unclear. Here, we provide sedimentary, pedogenetic, geochronologic and provenance sand data of a new site "Chigualoco" in north central coastal Chile (31º S, 71ºS). The site is located few km south of the Estero Chigualoco and tens of km north of Estero Conchali, both coastal catchments and representing potential sources of the sands outcropping in the Chigualoco stratigraphic section. The site at 70 m a.s.l. and 0.5 km from the coastline includes a stratigraphic sequence with five paleosols and four paleodunes in a 15 m section. The chronology is based on luminescence ages determined using a pIRIR225 (post infrared, infrared stimulated luminescence @ 225°C) single aliquot regenerative (SAR) dose protocol for potassium-rich feldspar. This approach has been successfully applied in previous studies by the authors (e.g. García et al. 2019) and has been proven to provide reliable chronologies for the aeolian sediment record of central coastal Chile. We discuss the implications of this new record in terms of paleoclimate forcings and also factors controlling the formation of paleodunes. We use this occasion to contrast the role of Andean versus coastal catchments in forming paleodunes in the study area.

Variance of ostracod assemblages in a dynamic deltaic system during Late Holocene times: case study Danube Delta, Romania

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Deltas are dynamic and unique natural systems impacted by many natural factors, such as wave and river influence, erosion and accumulation processes, along with subsiding and uplifting movements. The Danube River – Danube Delta – Black Sea is the most extensive river – sea system in Europe. The Danube Delta developed in the Quaternary when Danube started to flow into the Black Sea basin.

The present study is focused on the variations of the ostracod assemblages inflicted by the formation and evolution of Razelm-Sinoe lagoon system during late Holocene times. This lagoon complex is located in the southern part of the Danube Delta and consists of several lakes/lagoons that occupy about 85% of its surface. Multidisciplinary investigations were done on a 7-meter-deep core recovered from the western bank of the lagoon, currently located about 14 km from the Black Sea shoreline. During the Holocene, the development of this area was influenced by the local sea-level changes, shifting from brackish lagoon to a freshwater lake environment. The identified ostracod assemblages revealed salinity changes ranging from oligohaline to mesohaline conditions. The dominant mesohaline taxa are represented by *Cyprideis torosa*, *Heterocythereis amnicola*, *Amnicythere olivia*, *A. pediformis* and *Loxoconcha gibboides*. The mesohaline environment also contains benthic foraminifera represented almost entirely by abundant *Ammonia tepida*. The most representative oligohaline ostracod species are *Darwinula stevensoni*, *Candona neglecta*, *Pseudocandona compressa*, *P. albicans* and *Limnocythere inopinata*.

This study offers new insights into the Late Holocene paleoenvironmental and paleogeographic changes that took place in the Razelm-Sinoe lagoonal system. During the last 3000 years BP this area evolved from a freshwater wetland/reed marsh to a marine/brackish lagoon environment with episodes of opening and closuring, leading to salinity oscillations.

Holocene sea-level and storminess variations recorded at Kolga strandplain, northern Estonia

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Holocene relative shoreline displacement and architecture of the Kolga coastal strandplain in the tideless southern Gulf of Finland are reconstructed using airborne LiDAR-based relief analysis, ground-penetrating radar (GPR) surveys, sedimentological and magnetic susceptibility (MS) analyses, and luminescence and AMS radiocarbon dating. The results show that this coastal system consists of at least 24 prominent swash-aligned ridges (some with aeolian aggradation) represented by mostly seaward-dipping (offlapping) sandy-gravelly coastal deposits. Its landward segment (~50% of strandplain width) consists of 12 traceable ridges formed during the regressive phase of the Ancylus Lake and Initial Littorina Sea between 11.1 and 9.6 ka. Following a ~5 m transgressive episode, which is visible in GPR records as a regional disconformity, the seaward ridge set a prograded at substantially slower rate during the subsequent Littorina and post Littorina Sea phases between 6.6 and 0.3 ka. This episode caused a rise in groundwater level that initiated peat formation in Ancylus-age paleo-swales, at progressively higher altitudes (onlap), between 8.4 and 7.1 ka BP at 22 and 25 m above mean sea level, respectively. GPR images show that at least 13 additional low-relief coastal ridges are buried by peat deposits in the older part of the strandplain alone. Subsurface truncations, variations in beachface gradients, and heavy-mineral anomalies in beach and dune sections likely reflect long-term storminess patterns. Our study demonstrates the potential of the Kolga complex as a geological archive of relative sea level (beach/dune contact and basal peat chronology) and storminess in the eastern Baltic Sea area.

Abrupt and extreme climate changes over the Late Glacial Stage

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Public awareness of extreme climatic events has risen sharply in recent years, partly because media attention emphasises the catastrophic nature of floods, droughts, storms, heat waves or cold spells. However, extreme events are also recorded in the geological record and their relationships to undetected millennial-scale climate cyclicity is crucial to assess any natural hazard evaluation. Coastal landscapes are among the most sensitive systems to abrupt climate changes and important archives of past and ongoing climatic changes. They can be used to reconstruct future scenarios potentially undergoing toward recurrent extreme climatic events. Four sites, located almost at the same latitude, were chosen to define how climate changes have modified the landscape and, in places, human adaptation during the last 125 ka, from the Last Interglacial (Marine Isotopic Stage-MIS 5e) to the Present (MIS1). The sites were selected because of detailed sedimentological, stratigraphical and geomorphological studies. They are located in North-West Sardinia (Porto Palmas), Tuscany (Baratti), Lazio (Circeo) and Apulia (Romanelli Cave). In all selected areas the Last Interglacial high-stand sea-level indicators are tidal notches or marine terraces buried by continental deposit attributed to the subsequent low-stand glacial phases (MIS 4-2). At Porto Palmas aeolian dunes cap valley fills and alternate with alluvial fans, dated between 70 ka and 8 ka. At Baratti, the alluvial record spans from about 108 ka to 15 ka. Circeo is characterised by alluvial fan and palaeosols deposits referred to MIS3. At Romanelli Cave the sedimentary record is made of sands, silts and clays deposited from MIS5 to MIS1 (10 ka) alternating with flowstones dated at 120 and 40 ka.
In order to improve and test the chronological settings of the cited Late Pleistocene successions we integrated the existing radiometric ages (U/Th, ^{14}C) with Luminescence dating. The preliminary results highlight how sedimentary systems evolve and behave under rapid climate fluctuation referable to Dansgaard-Oeschger and Henrich events, opening new scenarios for studying the potential cyclicity of extreme events.

Rise and decline of Holocene tufas across Europe: exploring east/west and north/south similarities and differences in the climatic and anthropogenic impacts on their development

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Since the 1990s, the postulate that there would be a marked decline in the deposition of calcareous tufas in Europe since ca. 2500 BP (Goudie et al., 1993) has been widely discussed as a growing number of studies provided evidence of deposits developing until our present days. We recently demonstrated that the 'late-Holocene tufa decline' is actually a general view of a rather complex tendency: after a maximum during the Atlantic period, fluvial tufas are systematically affected by a decline from ca. 5 ka cal. BP but no general trend is shown in the development of proximal (spring-fed) or lacustrine tufas (Dabkowski, 2020-QSR). Using the same, updated, inventory of well-dated deposits, we here investigate similarities and differences across Europe in the timing of tufa onset and decline during the Holocene.

Eastern deposits start developing then reach a maximum slightly earlier than western tufas. Afterwards, they show a relative decline from ca. 6 ka cal. BP in the east and ca. 5 ka cal. in the west. Marked east/west differences in the timing and intensity of the climatic improvement during the first half of the Holocene explain the earlier development of eastern tufas compared to the west. After the Atlantic optimum, climatic variations become narrower and cannot explain on their own the decline observed both in the east and west, suggesting a strong influence of anthropogenic modifications in all Europe since the Bronze age.

Comparing southern deposits to other European tufas, significant differences in both their development and decline are observed, whether all or only fluvial deposits are considered, reflecting the important decoupling between Mediterranean and mid-latitude climatic records. However, the earlier and more intense tufa decline observed in the mid-/northern part of Europe is more likely to results from an earlier and faster development of farming and related deforestation at European mid-latitudes compared to southern Europe.

These data re-emphases the close relationship between tufa development and both climatic and anthropogenic changes but demonstrates spatial differences in the modalities of those impacts.

Quaternary travertine deposits derived from the recent activity of the Alhama de Murcia fault, Eastern Betic Cordillera, Spain.

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Continental carbonates, such as travertines and tufas, formed from CO_2-rich groundwater degassing as it emerges at the Earth's surface, are often associated with major crustal-scale faults. The Rosel site, in the Lorca-Totana section of the Alhama de Murcia Fault, Spain, presents a complex geomorphological landscape controlled by active tectonics. The Alhama de Murcia Fault is an 80 km long left-lateral strike-slip fault that is one of the main seismogenic structures in the Iberian Peninsula. In this work, we analyzed the carbonatic materials present in the Rosel site through the study of SEM images, thin sections and chemical analysis to determine the origin of these quaternary deposits. The aim is to explore the relation between quaternary travertine precipitation and the tectonic activity of the fault through morphological and geochemical studies. The $\delta^{13}C$ and $\delta^{18}O$ isotopic signals indicate that the origin of the carbonate deposits in the Rosel site are hydrothermal. In addition, the $^{87}Sr/^{86}Sr$ ratios in the samples suggest subsurface fluid interaction with the Miocene sediments and the Alpujárride basement, located below the alluvial deposits. The tectonic activity in the Alhama de Murcia Fault generates the opening of the deep water circulation in the crust every time a seismic event occurs, giving rise to the precipitation of hydrothermally derived carbonates. The deep waters rise and reach the surface interacting with the meteoric waters, resulting in the travertine formation. Therefore, the Rosel carbonate deposits study can inform us about the seismogenic cycle of the Alhama de Murcia fault in the Lorca-Totana section.

Uranium content in Italian Quaternary travertines and calcareous tufas: a review

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A database consisting of 163 data of uranium content and $^{234}U/^{238}U$ initial activity ratio, from 15 Italian Quaternary travertine and calcareous tufa sites, has been compiled from the relevant literature. Applying a graphical method, data have been interpreted considering the uranium geochemistry in natural environments as well as the geological, hydrogeological and hydrochemical setting of each site. The U content and $^{234}U/^{238}U$ initial activity ratio in travertine and tufa appears to be due to interaction among different factors, such as the availability of U in the aquifer rocks, the redox state of the waters, and the water/rock interaction in the aquifer. Three groups of travertines/tufas, characterized by different U concentration and $^{234}U/^{238}U$ initial activity ratio, were identified; the groups include: i) carbonates precipitated from groundwater circulating, with short/fast flow path, in volcanic rocks with high radionuclide content; ii) carbonates precipitated from groundwater circulating, with long and/or the deep flow path, in carbonate/evaporite formations with relatively low radionuclide content; iii) carbonates precipitated from cold-waters associated to river systems, which are characterized by oxidized conditions and fed by high-discharge springs recharged by carbonate aquifers. Mixing between waters from different aquifers and different geochemical characteristics occurs frequently in the sites investigated. This interpretative model might be applied to other fossil travertine and calcareous tufa and contribute to reconstructing the paleo-environments of ancient depositing systems.

Eemian continental reference sequence for NW Europe: multidisciplinary study of the Caours tufa (France).

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Investigation on the Quaternary interglacial deposits of the River Somme basin have allowed the discovery of an exceptionally well preserved calcareous tufa formation overlying an alluvial sequence at Caours on the lowest fluvial terrace of the Scardon River (tributary of the Somme). The basal periglacial gravels lies at + 6m above the modern valley bedrock and belongs to the lowest terrace within the Somme terrace system. The calcareous tufa is separated from the underlying periglacial alluvial gravels by fluvial calcareous silts overlain by a marshy soil and a thin peat layer. The whole sequence, has provided abundant malacological faunas allowing palaeoenvironmental and climatic reconstructions. The initial overbank fluvial silts yield assemblages of open ground including cold-loving species allowing the recognition of Lateglacial climatic conditions. In the upper part of the silts, land snails communities reveal a dramatic change to open forest environments indicating early Interglacial climate. Subsequent full temperate faunas in the tufa contain increasing amounts of forest snails, these are up to 70% in the last organic layer and correspond to the climatic optimum of the Interglacial. The upper part of the tufa shows a progressive decrease of the most thermophilous snails. Tufa geochemistry ($\delta^{18}O$ and $\delta^{13}C$) provides results consistent with this interpretation. The lower part of this sequence (»0.5 m) includes organic tufa horizons (micro marshy soils) that have yielded thousands of large mammal remains and Palaeolithic flint artefacts. Geochronological data obtained on U-series (TIMS) dates from stromatolith calcite crystals and TL dates from heated flints confirm the allocation of the archaeological layers to the Eemian optimum (MIS 5e: 123±3 ka /11 dates). Palaeontological, dating and archaeological approaches at Caours allow a very detailed reconstruction of the evolution of palaeoenvironments from the end of the Saalian and during the last interglacial. Moreover Caours appears now as one of the most complete and well preserved Palaeolithic site in Europe for the Eemian optimum demonstrating that Neanderthal was fully adapted to forested habitat and a temperate climate.

Ages and temperature of the Vértesszőlős Early Human site (Hungary)

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During the Lower Palaeolithic, Central Europe is regarded as having a key position between the Near East, Central and Southern Asia, Mediterranean and Western Europe, being located on the “Out of Africa” route. At Vértesszőlős (Hungary), important archaeological settlements and remains of *Homo heidelbergensis* were preserved in loose sediments and tufa pools deposited at both glacials and interglacials from 557–223 thousand years ago (ka), corresponding to marine isotope stage (MIS) 14 to 7, with a peak at MIS 9. Tufa ages of 223 (±27) and 227 (±24) ka at the occipital bone confirm the overlap of *Homo neanderthalensis*–like and *H. heidelbergensis* fossils in Europe. Clumped isotope-based temperature of tufas range from 8 to 19 °C and 11 °C during the precipitation of the tufa containing the human occipital bone. The tufa–pools were thus slightly cool and their temperature have changed through time. The calculated $T(\Delta_{47})$ values do not follow the global MIS 9 to MIS 8 cooling trend, whereas the calculated $\delta^{18}O_{water}$ values range between –11.7‰ and –9.9‰, consistent with waters infiltrated during glacials. Due to relatively large analytical uncertainties, glacial and interglacial periods cannot be differentiated based on the present data set. Only a few MIS 9 paleoclimate records are available from Central Europe, and our clumped isotope-based temperature and $\delta^{18}O_{water}$ estimations are the first carbonate-based paleoclimatic evidence available from the Carpathian-basin for reconstructing the environment in which *H. heidelbergensis* lived.

Proxy records of Early-Middle Pleistocene Karahallı travertines for depositional environment and palaeoclimatic changes (Uşak, SW-Anatolia)

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The Karahallı travertines are situated in the north of the Baklan Graben in SW-Anatolia. This graben is formed as a NE-SW trending basin developed due to the extensional regime during the neotectonic period in the region. In this study, palynological, sedimentological, radiometric dating, and stable carbon-oxygen isotope of the Quaternary depositional system were firstly investigated. For this aim, 4 deep borehole logs (K-2, K-3, K-5, and K-6) included travertine levels were examined besides field observations. The results of this study contribute to a better understanding of the paleoenvironmental and palaeoclimatic changes of the investigated area as well as SW-Anatolia during the Quaternary period. Travertine precipitation was detected upper part of the Pliocene lacustrine deposits consisted of coal-bearing mudstone, clay, and clayey limestone. These travertine deposits, which have a thickness of about 40 meters, have interbedded with clastic inputs when travertine accumulation decreases or ceased. The Karahallı travertines were precipitated in a depression depositional system in the lacustrine environment characterized by micritic (laminated), reeds, pisoids, intra-clasts, extra-clasts, and algal levels. Travertine deposits are characterized chiefly by high depositional rates, horizontal bedding, low porosity, and permeability. Ostracod, gastropod fragments, and algal (Charophytes) forms are commonly observed. The ^{230}Th analysis on travertines selected from core samples were performed and according to dating results, these terrestrial carbonates continued to precipitate during the Middle Pleistocene (~288ka) In addition, $\delta^{13}C$ values of the Karahallı travertines are between -3.24 ‰ and 1.86‰ (V-PDB), while $\delta^{18}O$ values range from -9.67 ‰ to -8.36 ‰ (V-PDB). The oxygen isotope ($\delta^{18}O$) values recorded from lacustrine successions decreased significantly from the MIS 10 (cold-arid) to MIS 9 (temperate and rainy). 7 core carbonate samples were compiled for palynological analysis and due to pollen results, the Middle Pleistocene (MIS 10) microflora is characterized by dry herbs (NAP) and woody plants (AP). Moreover, the hydrothermal water influx played an important role in forming travertine precipitation and this might be strongly concerned with the active fault systems in the study area.

Asymmetric fissure-ridge travertine formation in active contractional zone: a structural inference (Yurtbaşı-Van/Türkiye)

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Eastern Anatolian Contractional Province (EACP) is characterized by a N-S compressional tectonic regime generated by the collision between Arabian and Eurasian plates. This tectonic regime is predominantly represented by E-W trending thrust faults, conjugate strike-slip faults, and rare normal faults. The region is also active in collision related volcanism. An asymmetric fissure-ridge travertine deposits are determined in the north of that collision zone, at the Yurtbaşı-Van (Türkiye). The Yurtbaşı Fissure Ridge Travertine having 700 m length and 70 m thickness. Travertine is mostly composed of bedded travertine deposits which formed as a result of flowing of surface waters. Banded travertine deposits are not observed due to lack of an active fracture. N-S aligned warm spring water (20-25 °C) pools are located on the top of the ridge. Disorganized water leakage zones determined on western wall of the ridge are interpreted as subvertical vein formations reached to the wall. Fissure ridge travertines are considered as ideal phenomena for identification of extensional deformation. Yurtbaşı Fissure Ridge Travertine formed as a N-S trending asymmetric ridge is one of the rare examples of extensional based syntectonic deposition at the Arabian and Eurasian collision zone.

Travertines between karsts and tectonics: a support for the analysis of fault activity and seismic hazard in Southeastern France?

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Promising new results have been obtained on calcareous tufa/travertines sequences in the vicinity of faults in the south-east of France, an area considered to be of moderate seismicity (seismic zoning of France).
The first results were obtained on the following diachronic and regional formations: 1) the St Antonin sequence, close to the Sainte Victoire thrust; 2) the Thomassine formation (Manosque), close to the Middle Durance fault, and finally 3) in the ravine of Castillon (Ségriès), on a small local dexter strike-slip with verticalization and rupture of the deformation in close relation with the major thrust of the Castellane arch.
The approach uses pXRF analyzes to determine the elemental composition of the carbonate/calcareous tufa and travertines concretions in order to identify the origin of the waters: karstic or with a link between tectonic accidents and mineralization of springs?
Several studies have already displayed the capacity of travertine and tufa to trap a large proportion of metals and minerals in solution or in suspension in the water.
The first sites analyzed present elements absent from the surrounding lithologies and local environments (e.g., S, Zn, Pb, Cu, Nb, Mo). It highlights a (potential) deep origin of the waters (raised by faults or fracturing) and indicates a significant contribution of these systems in the genesis and development of regional calcareous tufa and travertine sequences.
This provides crucial information on the detection of new potentially active tectonic and fault ruptures through a simple and directly applicable fieldwork method.
The different approaches and methods developed within the DystraPaRnat program (CNRS INSU) combine the use of geomorphological/climatic markers (paleohydrology of travertine and detrital systems) with elemental geochemical analyses (of concretions fed by fluids transiting through faults and fracturing).
Applications in the Southeastern France provides a regional context clearly supported by the number and quality of the calcareous tufa and travertines of the Upper Quaternary.
This allows to associate long-term environmental information (since 100 ka) to the analysis of the notion of natural hazards in the studied area in an original and innovative way.

The buried travertine body of Prima Porta (Central Italy): a multidisciplinary approach to understand its genesis and subsurface setting

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The results of recent studies carried out on a buried travertine deposit are presented. Travertine was identified in a drilling at Prima Porta, north-west of Rome (Italy), on the western boundary of the Tiber valley, a morpho-tectonic depression of extensional origin. This travertine was investigated using a multidisciplinary approach that included stable isotope geochemistry, mineralogy, petrography and radiometric dating, with the aims of understanding the depositional setting of the paleo-travertine system, the origin of travertine-depositing paleo-fluids, and the major processes controlling the formation and evolution of the travertine body. Geophysical and geochemical techniques (ERT, seismic refraction, ambient noise measurements, and CO_2 and ^{222}Rn concentrations in soil-gas surveys) were also applied to detect the subsurface setting of the fluvial incised-valley where the travertine body intercalates between alluvial deposits of the Tiber river.

Prima Porta travertine is associated with the rise of a deep-seated, hypothermal, saline, CO_2-rich fluid. According to macroscopic features of core (i.e., horizontal to sub-horizontal, irregular, wavy laminations) and microfacies associations (i.e., micrite crusts and rafts, both intercalated within and between the shrubs), travertine deposition was associated with a low to moderate energy environment, such as gently-dipping, shallow pools on low-angle, terraced slopes. U/Th dating suggested that activation of the travertine-depositing spring was probably coeval with the wettest climatic conditions occurring during MIS3, whereas the end of deposition coincided with the cold and arid phase of the last glacial maximum.

Applying non-invasive geophysical and geochemical methods, which complement each other, the geometry of the buried travertine body was defined and the subsoil structure of this sector of the Tiber valley was delineated. The upper surface of the travertine body appears to have a curved shape, gently dipping towards the E to the present-day Tiber river, forming a concave-upward section wedging out toward the S. Due to its hydrothermal origin, this travertine is hard and crystalline material, poorly porous, and consequently its specific electrical resistivity values were relatively high with respect to those measured in the embedding alluvial sediments (silt and silty sands).

Interbedded history of Holocene tufa and alkaline peat formations in the Somme valley (France)

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During the Holocene, concomitant formations of peat and calcareous tufas are recorded on chalky basins of north-west Europe (Belgium, Netherlands, Germany, Poland). Since the 19th century, geologists have recorded tufa-peat formations on the valley floor of the Middle Somme valley. Two systems of calcareous tufa have been identified in the midst of the peat deposits: 1) in dome-shaped tufas that wind through the valley and overhang the actual peaty valley floor by about three metres and 2) in lateral banks below the chalky cliffs. The interstratification with the peat deposits shows both simultaneous growth and different hydraulic conditions. The relationship between these sediments is still poorly documented, but offers possibilities for complementary palaeoenvironmental reconstruction.

New fieldworks have provided a better understanding of these tufa-peat alternations. Stratigraphic surveys (tufa-peat sections and auger coring) of the Bourdon-Tirancourt sector and a GIS study of the valley floor were carried out, in order to characterise the geometry of the deposits and the environmental evolution during the Holocene. These surveys showed that the tufa domes developed in a paleochannel and at the bottom of dry valleys. Supplemented by a malacological study of a tufa dome in Bourdon and radiocarbon dating on peat, a first chronology of interstratification and environmental conditions is emerging to document the evolution of the water regime and aquifers of the valley floor during the Holocene.

The development of tufas begins in the Preboreal period, according to the dating and several archaeological artefacts embedded in tufas. From 2300 BP the deposits became more silty and their formation was interrupted during the Iron Age. The peat preserved alongside the tufa dates from the Subboreal (around 3500 BP). Thus, the altitude of the top of tufas would indicate a more important peaty filling which has undergone a strong degradation (erosion, mineralization) and heights of water tables much higher than those observed nowadays.

Key words : calcareous tufa, fens, Holocene, fluviatile dynamics, Somme valley, France

Organic Biomarkers in Modern Terrestrial Carbonate Deposits

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Terrestrial carbonate deposits, such as tufa and travertine, provide long term, continuous depositional sequences in many different environments. In trying to reconstruct vegetation and hydrological changes in the past, traditional stable isotope analyses ($\delta^{13}C$ and $\delta^{18}O$) of carbonate minerals within these deposits are often difficult to interpret due to fractionation during the deposition of carbonate minerals in these systems. However, given the co-deposition of carbonate minerals with organic remains from plant material and microbial life, these deposits can serve as archives of organic biomarkers. Analysis of these organic biomarkers within tufa and travertine deposits would allow for the potential reconstruction of hydrological (δD_{lipid}) and vegetation ($\delta^{13}C_{lipid}$) changes without the complications of fractionation during mineral deposition. Here we will present initial results from a pilot study on the preservation of lipid biomarkers in modern tufa and travertine forming in the Ararat Valley, Armenia and the Jordan Valley, Israel.

Tufa or travertine deposits in hyperarid basaltic regions: the singular case of the Khaybar oasis (NW Arabia)

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Carbonate deposits have just been discovered in the Khaybar oasis, in a desert area of the northwestern Arabian Peninsula. This oasis, located at the head of a catchment, is established in wadis that incise the Precambrian basement and the overlying Pliocene basaltic flows.

For the moment, six outcrops of these carbonate deposits have been identified within it and present several similar characteristics: they are currently inactive, highly indurated, and located on the basaltic slopes between 1 and 5 metres above the valley floor. Most of them are characterised by alluvial facies, and show a low sedimentary thickness (50 to 100 cm) and sometimes remains of continental molluscs or root systems. One outcrop is distinguished from the previous ones by a greater thickness (3 metres) and by a dam morphology across the wadi and by waterfall facies.

Such types of deposits remain largely unknown in this region, and more generally at these low latitudes. Indeed, the geological and climatic context makes this case study quite singular and already raises many questions about the presence and nature of these deposits. The first question we will try to answer concerns the origin of these deposits: are they thermogenic or meteogenic? The faulted Precambrian basement and the presence of aquifers in the basaltic flows keep the question open. Preliminary isotope tests should answer this question. Another unknown factor concerns the age of these deposits. Are the six identified outcrops synchronous or do they reflect different wet phases during the Pleistocene? Different dating methods will have to be used to determine their chronology: U/Th, OSL and possibly ^{14}C if the deposits allow it.

Depending on the answers to these questions, these deposits could constitute an unexpected palaeoenvironmental or even palaeoclimatic record in the Arabian Peninsula.

Analyses of Tsagaan Lake Sediment, Valley of The Gobi Lakes, Mongolia, to Understand the Past Environmental Changes and the Effect of Ongoing Global Warming

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The arid region of Mongolia is a sensitive region to climate change. Understanding global warming plays an important role to predict further climate changes. In this study, we aim to investigate the relationship between the climatic factor and sedimentation history on the centennial timescale (<100 years). We retrieved a core sample (136 cm depth) from the Tsagaan lake in the Valley of the Gobi lakes, Mongolia. The sediment core mainly consists of clay and silt sediments, occasionally interrupted by the sand-dominated layers. The sediment characteristics such as water, organic matter, carbonate, silica concentrations, and grain size were measured by 1 cm intervals. The major elemental composition was measured in 10-cm intervals using the XRF analysis. ^{210}Pb dating method was applied and three age models under the assumptions of Constant Rate of Supply (CRS), Constant Initial Concentration (CIC), and Constant Flux and Constant Sedimentation (CFCS), were investigated for the sediment chronology. In addition, a self-calibrating Palmer Drought Severity Index (scPDSI) was calculated for the study area using the Climate Research Unit (CRU) data (Harris et al., 2020). The CRS model revealed that the upper 26 cm sediment spans the sedimentation history of the last 87 years, which is more reliable than the CIC and CFCS models. The drought period (negative value of PDSI) is coinciding with the abundance of organic matter, carbonate, and silica with the coarser particles in the lake sediment. This result is also evidenced by the significant correlations of loading plots in Principal Component Analysis. The major elemental composition of sandy layers in the sediment core corresponds well with that of mobile sand in the catchment. The sandy layers are likely to indicate the aeolian activity in the past.

Dating early Quaternary aeolian deposits unravels coeval links between climate, tectonics, and erg generation

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Evaluating the impact and implications of aeolian repositories that mark large-scale climatic transitions requires knowledge about the timing of their emplacement and the mechanisms responsible for their production, which remain highly uncertain. Here we apply numerical modelling of cosmogenic nuclide data measured in aeolian sand using two independent dating methods. Nineteen samples were collected in the largest continuous terrestrial body of sand on Earth, to determine settings under which the sand was generated, by constraining the timing of sand introduction into the interior of southern Africa. Our findings reveal that major events of sand formation and accumulation in the Kalahari Desert occurred between ~2.2 and 1 Myr ago. The establishment of the Kalahari sand field corresponds to regional, continental, and global scale climatic and morphotectonic changes that contributed to the mass production and widespread dispersion of sand. These changes substantially altered existing habitats, thus constituting a crucial milestone for flora, fauna, and hominins in southern Africa during the Pleistocene.

Timing of aeolian sediment deposition in eastern central Asia during the Late Quaternary

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Aeolian sediments are widespread in Central Asia and can provide important information on past climates. Accumulation phases are often interpreted as either strong aeolian activity or / and increased moisture, leading to the (final) sediment deposition. However, the interpretation is highly site specific and depends on several factors, e.g. sand availability in the source area and transport rate. For this study, optically stimulated luminescence (OSL) ages from aeolian sands and silts were analysed. The study area is covering heterogeneous landscapes like the Tibetan Plateau, the deserts of northern China, the basins of southern Mongolia and the mountains of central Mongolia. The timing of aeolian sediment deposition strongly varies between these regions. On the northern Tibetan Plateau, strong accumulation took place in the late Glacial and the early Holocene. This was followed by a second phase of aeolian reactivation in the late Holocene. In contrast, much older ages were obtained from the deserts of northern China, covering most of the Late Quaternary with clusters during the last glacial maximum (LGM) and the Holocene. In the large basins of southern Mongolia, aeolian sediments are mainly from the late Holocene, while aeolian sediments in the mountains of central Mongolia were continuously deposited since the LGM. Beside changes in moisture, e.g. due to variations in the Asian summer monsoon, the preservation potential of the sediments largely affects the regional aeolian stratigraphies. The preservation potential is particularly high in the deserts of northern China, due to the large amount of sand available. In contrast, aeolian sediments on the northern Tibetan Plateau and especially in the basins of southern Mongolia are frequently reworked, due to a lower amount of available material. Consequently, only few sediments dating back to the LGM exist. The generally finer sediments in the mountains of central Mongolia might have been preserved due to constantly wetter climate conditions and a therefore reduced remobilisation potential. Interpreting OLS chronologies from large areas with different environmental settings provide important information on climate changes, e.g. monsoonal variations. However, site specific information are extremely relevant and might complicate the supra-regional interpretation.

Interpreting aeolian dynamics by integrating cosmogenic nuclides and OSL (Cosmolian)

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Dunes are a common landscape found across a wide range of climates and environmental conditions dominated by aeolian activity, and are often used for palaeoenvironmental reconstructions and landscape evolution studies. Recent developments in the dating of aeolian landforms in arid climates integrated cosmogenic nuclides and OSL dynamics to date aeolian landforms at the million-year time scale (*Cosmolian*). In this study, the vertical movement patterns of the one-dimensional *Cosmolian* model are investigated using multiple advanced time-series analysis approaches in order to determine whether model simulations that converge to a common cluster share similar dynamical properties related to dune mobility. By comparing the model simulations that cluster into coherent dating against background simulations, it is revealed that several dynamical properties are required in order to obtain the observed cosmogenic nuclides concentrations in dunes in some of the largest deserts on Earth. These findings may imply that aeolian processes are dictated by inherent dynamical features that control the pace of aeolian activity and dominate dune formation and mobilization across the world. This study presents a novel approach to the investigation of dune dynamics at the million-year timescale using time-series analyses, which sets the grounds for an improved understanding of aeolian dynamics over millions of years.

How old is a desert? New constraints on the Kalahari Desert age revealed by integrating cosmogenic nuclides and OSL (Cosmolian)

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The wide extent of sand dunes in aeolian landscapes across continental interiors calls for improved dating and understanding of their morphodynamical properties for palaeoenvironmental reconstructions and for interpreting landscape evolution. However, the study of aeolian landscape evolution at the million-year timescale is difficult to achieve due to the interaction of different factors affecting dune migration and their self-destruction nature of chronostratigraphic information, which limits the applicability of traditional luminescence dating methods to ages younger than ~200 Ka. In this study, we present a new development for dating aeolian landscapes by simulating aeolian processes coupled with numerical modelling of cosmogenic nuclides accumulation based on luminescence-derived chronologies. This approach reveals ancient phases of sand introduction into the landscape, and provides an empirical process-oriented model that is packaged within a standalone program (Cosmolian), which facilitates the study of aeolian processes over multiple timescales. The new program was successfully applied for the Kalahari Desert in Africa and the Australian Simpson Desert, where it unfolds the timing of sand introduction into the landscape, corresponding with substantial changes in environmental settings. The correlation between the results of the Cosmolian model and the established paleoenvironmental framework exemplifies the applicability of process and data-based modelling in revealing key landscape evolution events in arid environments that may be identified by studying aeolian landforms.

Star dunes – A new combined research approach to deciphering their formation

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Complex star and mega dunes still remain, in contrast to small scale dunes like barchans, one of the most understudied aeolian bedform on Earth due to their unstable nature in time, overall size as well as morphometric and stratigraphic complexity. Due to these attributes our understanding of star dune morphometries is lacking sufficient detail and their influence on formation and evolution remains mostly theoretical. Capturing these complex features on surface and subsurface levels, in needed detail, represents significant technical challenges which have to be addressed and overcome to understand these dune forms.
We therefore applied a new approach combining high-resolution multitemporal surface changes reflecting actual aeolian dynamics with subsurface stratigraphical records describing older accumulation patterns. Our main research object for this approach is a complex star dune in Erg Chebbi, Morocco, which was analyzed over a timespan of four years (2018 – 2022) at two-year intervals using Terrestrial Laser Scanning (TLS), Real-Time Kinematic Global Navigation Satellite System (RTK-GNSS) and Ground Penetrating Radar (GPR). Multitemporal high-accuracy 3D surface models created form TLS point clouds were used for morphometric analysis and direct surface change analysis, which relates to sand transport summarizing the actual movement of a complete and complex star dune surface. The stratigraphical subsurface models created on all major dune branches via GPR, reveals relative depositional history and past movement of its major arms.
Our results showed the effects of a so far hardly observed shielding effect, pointing to a form of self-sustained dune growth, which has not yet been described in such spatial detail. This effect leads to the formation of isosceles dune arms with maximum inclinations which are found not only on star but also on other larger dune forms. Overall the methodic concept of combining surface and subsurface models on such large aeolian bedforms using highly resoluted data is promising and can be applied on all scales. Additionally, the suggested approach allows systematic drilling and sampling for luminescence dating to understand the chronological formation of these complex mega dunes in higher detail.

Terracettes in the hyperarid Atacama Desert – fog-driven landforms of Holocene age?

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Terracettes are quasi-contour parallel step-like microtopographic features consisting of repetitious platform-type benches and slope-type risers and are documented from hillslopes in a range of climates. While a number of studies emphasize their formation by trampling of livestock and grazing animals (cat steps or stock trails), it has been shown that terracette formation may also be explained by a number of natural processes, including solifluction or freeze-thaw processes, slumping, soil creep, or vegetation control. Despite this variability and the controversy about their origin, these micro-terraces may alter hillslope soil moisture and vegetation patterns, infiltration and surface hydrology, as well as downslope sediment flux, potentially disconnecting downslope conveyance processes of surface runoff. Given the process mechanisms discussed in these previous studies, the extremely hyperarid climate of the central Atacama Desert in northern Chile may be regarded as unfavourable for terracette formation; here, livestock and grazing animals are absent, moisture availability is extremely limited, and frost processes in elevations below ~1000 m asl are rare. Nevertheless, here we report on terracette-covered slopes in the central Atacama Desert located close to the Rio Loa canyon in the Coastal Cordillera, that represents an important inland pathway for coastal fog in the Atacama Desert. Based on sedimentological and geomorphological investigations, UAV-derived aerial photos and soil moisture monitoring, we present geomorphological, stratigraphical and soil hydrological characteristics of the terracettes and discuss potential drivers of terracette formation. Our observations suggest a combination of wind and fog-related moisture supply, particularly during several day-long periods of sustained high relative humidity and fog occurrence, as the key driver for terracette formation, adding to the various processes discussed in previous studies. Finally, OSL dating of terracette platform sediments suggests a Holocene formation of the terracettes, thereby illustrating the importance of fog-driven active hillslope dynamics for shaping the desert landscape in the Atacama under present hyperaridity.

Biogeomorphology of nebkhas in the Mu Us dune field, north-central China: Chronological and morphological results

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Nebkhas, also known as nebkha dunes or coppice dunes, are a unique biogeomorphological aeolian landform that is common in arid and semi-arid regions. They are often regarded as a signal of regional desertification and could be potential dust sources due to their relatively large content of fine sediments, but they also serve as "fertile islands" that enhance biodiversity at a micro-habitat. How the interactions between plant growth and aeolian sand deposition affect the formation and development of nebkhas has not been well documented, though. In this study, the chronology and morphological features of nebkhas in the Mu Us dune field, north-central China were studied using radionuclide (137Cs) dating and unmanned aerial vehicle (UAV) photogrammetric survey. The results show that the nebkhas are mainly distributed around lake basins and dry river valleys with relatively flat topography. Most nebkhas have heights around 0.5–1.5 m, and according to a new integrated age-height model, they mostly formed in the last fifty years. Widespread nebkha growth over that time is interpreted as a response to both desiccation of lake beds and river valleys and a pronounced decline in strong wind frequency. The regular rounded shape of the nebkhas in the study area may reflect the growth form of prostrate, extensively branched *Nitraria tangutorum*, the dominant formative shrub, and response to the low-energy wind environment. A nebkha's height and horizontal length increase synchronously in the early stage of the development, while the increase in horizontal length and projected area accelerates when the dunes become larger. Feedbacks involving both aeolian sand transport and shrub growth can explain a decline in growth rate with increasing height and an apparent height limit of about 4 m. This study also implies that nebkhas are important biogeomorphological features demonstrating how biotic and abiotic interactions can shape landforms and influence ecological functioning in arid and semi-arid environments.

Sedimentology and geochemistry of aeolian sand in the Taklamakan Desert and Horqin Sandy Land, northern China: Implications for surface processes and provenance

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Dune fields of Quaternary age occupy large areas of the arid and semi-arid regions of northern China. However, limited research focused on understanding the provenances and Earth surface processes of aeolian sediment. This study examined the particle size distributions and geochemical composition (including major, trace, and rare earth elements: REEs) of 46 dune sand samples from the Taklamakan Desert and Horqin Sandy Land. The integrated data were used to explore the spatial variations in the characteristics of aeolian sediments and its drivers.

The mean Chemical Proxy of Alteration (CPA) and the Parker's Weathering (WIP) values both suggest the bulk samples from the Horqin Sandy Land experienced more intense chemical weathering, whereas physical weathering is a dominant process in the Taklamakan Desert. Furthermore, a combination of the index of compositional variability (ICV) and immobile trace element ratios shows that dune sand in the Horqin Sandy Land underwent more intense sedimentary recycling. These differences may be attributed to the fact that sediment supply was high in the Taklamakan Desert, which can shorten residence time exposure to chemical weathering and reduce the potential of the effective recycling for aeolian sand.

The Eu anomaly vs. $(La/Yb)_N$ diagrams suggest that the primary source-rocks contributing to the coarse (>75μm) and fine fractions (<75μm) in the Horqin Sandy Land are different but mainly derived from the Great Hinggan Mountains. In the Taklamakan desert, the Kunlun Mountains are the main source of the coarse fraction, whereas both the Kunlun and Tian Shan Mountains are the main sources of the fine fraction. Differences in the provenance of the fine- and coarse-grained fractions are primarily controlled by interactions between wind and fluvial systems. This study confirms that surface processes and sediment provenance in drylands of northern China have distinct spatial differences, implying that geochemical signatures in aeolian sand need to be interpreted in the specific climatic and tectonic contexts.

A Geoarchaeological investigation into the depositional and environmental context of southern Kalahari pan sediments in the Kgalagadi District, Botswana.

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The Kalahari Desert is a semi-arid landmass that has savannah plant cover and encloses the majority of Botswana in southern Africa. The Kgalagadi district, which is the main focus area of this research, is located in the southern part of this sand plain roughly 518 km south of Gaborone. There is a general paucity of archaeological and palaeoenvironmental research in the southern Kalahari, apart from research conducted on the South African side of the border (for example, Wonderwerk Cave and Kathu Pan). However, a recent survey and excavation campaign carried out in July-August 2022 reported surface scatters of stone tools made of mostly quartzite that fit Middle and Late Pleistocene typologies, implying the presence of human populations in this 'thirstland'. These surface sites are mostly located on the ridges above pans.

Pans (ovate depressions) frequently contain water during the rainy season and are a regular occurrence in the Kalahari along with their lunette dunes. The palaeoenvironment can be examined by investigating the relationship between the pans and their dunes. The presence of these seasonal waterbodies in the past could also have affected the site choices of early humans. Despite this potential, pans have been under-researched for the purpose of palaeoenvironmental reconstruction in a geoarchaeological context. An array of techniques and methods are employed to establish a broad spectrum, depositional and environmental history of the pans and lunette dunes. These include particle size analysis, Loss-On-Ignition analysis, X-ray powder diffraction (XRD), X-ray fluorescence (XRF), Fourier-transform infrared spectroscopy (FTIR), and a microfossil analysis. This contribution aims to elaborate on the present understanding of the palaeoenvironmental conditions in the southern Kalahari basin. The preliminary results of this geoarchaeological analysis (consisting of sediments from four archaeological test pits, six exposed profiles, and three geotrenches) as well as a detailed discussion of the methodologies used are presented. These results provide more detailed information on the depositional context of the Kalahari sediments, which will assist in the investigation of more intricate theories concerning the link between pans and hominin site choices.

The influence of valley damming on Quaternary Vega sequences on the Eastern Canary Islands

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The Canary Islands are formed by several volcanic periods since the Cretaceous. Later volcanic phases were able to dam up former developed valleys. Those valleys were acting as sediment traps. The deposited sediments are so called “vega sediments”, which are mainly composed of three different types of material: sediments of volcanic origin (tephra and lapilli), sediments of the surrounding slopes and dust deposits originating from the northern African continent. Two different layer types characterize the vega sequences. On the one hand there are calcium depleted reddish sediments with high clay content (max. 90%) interveined by calcium enriched, fissure-like structures and on the other hand, there are layers dominated by extensive carbonate enrichment (up to 45% $CaCO_3$), also characterized by the highest quartz contents.
So far, the descriptions presume an intense slope-vega connectivity with erosion and deposition cascades of high frequency but low magnitude. Thus, the formation of the vega sequences seems to be primarily driven by continuous translocation processes from the slopes to the valley floor, rather than by direct dust deposition or abrupt erosion events. Soil forming processes seem to be restricted to the slope positions since the drainage conditions within the valley floors (>80% clay) seem not appropriate to vertical processes like de- and recalcification. Finally, it is unclear to what extent soil-forming processes took place on the slopes and in the valley floor and how and when sediment transport occurred. In that system, the damming effect plays a key role within the formation of vega sediments but is poorly understood yet.
A new site on Fuerteventura gives now the opportunity to evaluate the influence of the damming, since this site shows a comparable setting but without a damming situation. Even though those sequences do not show such a clear alternation of two distinct layer types, several carbonate enriched layers ($CaCO_3$ up to 45%) are separated by carbonate free, clayey fissure-like structures (clay content up to 83%). The comparison between the sites should contribute to the general understanding of the formation conditions, and could pave the way for integrating those geoarchives in the overall context of environmental paleoreconstruction.

Sub-)Recent Earth surface processes in the Kaukausib Catchment, southern Namib Desert

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Many current Earth surface processes in dryland environments remain poorly understood. One reasons for this is that representative locations are often located in remote regions without long-term observations. The Kaukausib catchment in the southern Namib Desert is a prime example, where even under long-term hyper-arid climate conditions rare, but significant individual short-term rainfall events can trigger strong landscape changes. Here, remote sensing is a very valuable tool to overcome the lack of (modern) long-term data on Earth surface processes. The analysis of archived satellite images integrating over the longest possible observation period, starting from the 1970s/80s, may govern landscape formation over (sub-)recent timescales.

We present results on vegetation changes mapped by using multispectral optical imagery and several frequently applied spectral vegetation indices, such as the Normalized Difference Vegetation Index (NDVI). Area-wide mapping of the NDVI from 1984 to 2022 is conducted using imagery of the Landsat archive. Within this time period, phases of increased “greening events” can be inferred, e.g. between 1999 and 2012, but a general decline in vegetation vitality is suggested. In addition, permanent vegetation within the study area was mapped using Corona satellite imagery (acquired in 1976) in comparison to present-day conditions. This initial analysis reveals a decline in permanent tree vegetation between 1976 and today.

These outcomes obtained from earth observation archives are complemented by field-based geomorphological mapping and sedimentological characterization of exemplary sediment profiles. For this purpose, the deposition history of a sediment profile consisting of alternating layers of still-water deposits and dune sands is investigated by quantifying fallout ^{137}Cs and ^{239,240}Pu activities at different depths. First results indicate that the accumulation of still-water sediments trapped by a barrier dune and subsequent fluvial incision into these sediments of about one meter are likely to have occurred during the last 70 years. This timescale is largely covered by our remote sensing records, allowing for a direct comparison of the different methods

We see this combination as an innovative new approach to characterizing decadal changes and use such modern analogues as an important basis for the interpretation of landscape changes in drylands also over longer time periods.

Fluvial Responses to Aeolian Encroachment – Aeolian-Fluvial Landform Evolution along Dunefield Margins

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Aeolian-Fluvial (A-F) processes, in particular damming of fluvial systems by dunes along dunefield margins have been shaping Quaternary landforms in arid zones. At the northwestern Negev dunefield (Israel) margins, high-resolution chrono-stratigraphic analysis of stratigraphic sections revealing remains of truncated vegetated linear dunes and fluvial fine-grained deposits associated with dune-dammed water-bodies documented A-F controlled environmental changes. Nineteen stratigraphic sections in two basins were studied using Portable Optically Stimulated Luminescence (POSL) and OSL dating.

The fine-grained dune-dammed waterbody deposits infilled former fluvial morphologies forming alluvial plains. Three distinct A-F sediment types were discerned in these deposits : (a) event-based couplets, (b) massive structureless loam and (c) fine-laminas. Each impoundment was generated by slightly or distinctly different dune-damming and sedimentary mechanisms depending on the location of the damming-dunes that were found to gradually propagate downstream into the dunefield. The size and depth of the waterbodies were confined by the accommodation space upstream of the dune-dam, while deposition and aggradation depended on the flow capacity and available upstream source sediments.

The three major sand incursions into the NW Negev during the LGM, Heinrich-1 and Younger-Dryas resulted in temporal waterbodies impounded by single to multiple dune-dams. Dune-damming persisted, but not necessarily continuously until the middle-Holocene. The early Holocene A-F sediments along the dunefield margins may reflect a climatic shift characterized by energetic fluvial systems, coeval to Sapropel-1 deposition in the Mediterranean basin. During this period, the upper and widespread portion of the alluvial plains was formed. When the dune-dams were breached during the middle Holocene the alluvial plain was eroded by rapid and reopening, rejuvenation and incision of the fluvial system.

We demonstrate that nature of the interaction between the aeolian mass and the fluvial system determine A-F landscape evolution. Vegetated linear dunes are prone to defined periods of wind-controlled activation, and stabilization that form the dune-dams while dune stability and maintenance accommodation space and sediment flux control the gradual and lagged shift from a dune-dammed fluvial system to an open fluvial-dominated system.

High-resolution analysis of late Quaternary aeolianites on the southeastern Mediterranean coast of Israel

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Aeolianite ridges are petrified dunes deposited at low to mid-latitude coasts. Their location, structure, and lithification reflect changes in sea level, strong wind power, fetch parameters, and sediment availability. The Israeli coast has a chain of submerged and inland ridges running parallel to the southeastern Mediterranean coastline. They consist of alternating loose sands, carbonated sandstones and red, sandy paleosoils representing periods of reduced wind power and stabilization. Previous studies present low-resolution dating methods, and their finds are poorly correlated with climatic and environmental events related to deposition or lithification.

This study describes the vertical and lateral evolution of an elongated aeolianite ridge. This dune accumulated and lithified along the paleo-Israeli Mediterranean coast during the last glacial period. The objective is to explore the dune development at single-bed to sand package stages in time and their relation to local environmental conditions, regional climatic trends, and possible changes.

The methodology included a detailed Portable OSL analysis, OSL dating and sedimentological characterization. Sedimentological analysis shows that aeolian accumulation occurred as discrete laminae that built-up cross-bedded sediment packages. The loose laminae consist of quartz grains, while the lithified laminae are by calcium carbonate cement. Since cementation is parallel to the aeolian accumulation, indicating it’s a surficial process that occurred while the dune was still active and accumulating. It may mean microbiotic crusts activated by moisture conditions. This can serve as biomarkers for wind power and wetness duration.

POSL measurements have bright blue OSL signals (12-17 million) and very similar depletion and IRSL-OSL ratios demonstrating sedimentological similarity suitable for reliable POSL profiling. POSL profiling revealed a high-resolution and in-order chronostratigraphy. Suggesting that the sand laminations represent specific wind events at a very high seasonal to even diurnal resolution. Lateral POSL results reveal a value range evidence that doesn’t indicate any significant change in depositional age. In contrast, the vertical profile indicates a linear upwards decrease in count values. The trends also show that the quartz grains do not possess a saturated OSL signal. Upcoming OSL dating and outcrop image analysis will better constrain the accumulation rates and their possible connection to environmental and climatic drivers.

Luminescence Dating of Dunes in the Western Thar Desert: New Data and Regional Synthesis

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Luminescence dating of desert dune sands began in the Thar Desert and has revolutionized studies of global deserts. The Thar has been shown to be older than 200 ka, confirming its geological rather than human origin. Dune accretion / preservation was driven by the SW monsoon winds and post-date glacial epochs. After the LGM, short duration episodes of dune accretion occurred around 13 ka, 11 – 9 ka, 8 – 7 ka, 6 – 4 ka, ~2 ka and <1 ka. New optical ages are presented for linear, transverse and parabolic dunes in the western Thar. TL sensitivity of quartz was used as a surrogate for the change in sediment sources of the dune sands. Synthesis of new and previously published luminescence ages suggests:

1. Increased sand accretion during the past 500 a due to both increased anthropogenic activities and preservation bias.
2. Different types of dunes accreted both synchronously and asynchronously, suggesting a varied control of wind regimes and sediment supply. The absence of transverse dune records at different sites between 6 and 3 ka may indicate the limitations of sampling, or a shift to a more multi-directional wind regime that impacted sediment supply/preservation.
3. The sensitivity of the 110°C TL peak of quartz from dunes of ages between 7 and 2 ka is nearly twice that of dunes with ages < 2 ka and > 7 ka. This suggests a change of sediment source. Comparable sensitivity of quartz from current interdune suggests that it could be the source of dune sands during 7 – 2 ka. Higher sensitivity of interdunal sediment of >29 ka age was possibly due to sediment transport over long distances from the exposed continental shelf during low sea level.
4. XRD studies also suggest intermixing and change in sediment sources in the last 8 ka.

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Aeolian-Fluvial Deposits in Large Fluvial System along Dunefield Margins The Northwestern Negev, Israel

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Aeolian-Fluvial (AF) processes and dune-damming along dunefield margins generate amplified sedimentation in water-bodies upstream of dune-dams, comprising regional drivers of late Quaternary landscape evolution. While relatively small basins (<10 km^2) often remain dune-dammed until today, large fluvial systems are often been breached and reconstructing their depositional environment is difficult. The role of the pre-existing fluvial relief and basin size upon these dynamics is still unclear. We analyze Wadi Besor, the largest fluvial system (680 km^2) that transects the northwestern Negev desert dunefield (Israel) and provide evidence, despite its size, that the system underwent dune-damming in the late-Pleistocene. Chronostratigraphic sections along the main channel and tributaries with basins of different magnitudes were analyzed and correlated.

The main Besor channel incised into a Plio-Pleistocene peneplain forming a series of 7 alluvial terraces up to 30 meters above the present channel, with a lateral extent of ~3 km. AF stratigraphic sequences in the Besor and its largest tributary, Wadi Revivim, show that catchments at magnitudes of (>10^2 km^2) are composed of fine-grained and sand deposits that reflect the Quaternary sedimentary cover in the drainage area, i.e., loess and sand-sheets. Such relatively high-order basins document both late-Quaternary loess activity-reduction cycles and AF processes following the dunefield encroachment, characterized by dune-damming. The terraced relief and consequent channel depth of large basins permits accommodation space for such depositions.

Smaller middle-sized tributaries (<10^2 km^2) are more sensitive to local AF processes, i.e., single dune encroachments and fluvial erosion of these damming dunes. Thus, smaller catchments provide high-resolution palaeoarchives of aeolian and fluvial processes in the dunefield margin zone.

Radar amplitude as a tool for valley floor monitoring in the Atacama Desert during flood events

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Large volumes of sediment were transported downstream and disrupted the lives of the inhabitants of the Atacama valleys for several months (flooded urban areas, high death toll, etc.). The March 2015 pluvial event is the largest event to impact the study area (Cabré et al., 2020a,b; Aguilar et al., 2020; Garcés et al., 2022; Cabré et al., 2022).

We have tested the usefulness of the C-band Synthetic Aperture Radar (SAR) backscatter intensity (amplitude hereafter) (Sentinel-1) to track surface changes in the ephemeral valley floors of the Atacama Desert (27ºS) after flood events. SAR amplitude is an indirect measure of surface roughness and, therefore, grain size on un-vegetated surfaces is the parameter that plays an important role. Therefore, we have focused on an ephemeral channel to contrast SAR products with field measurements (grain size). To validate our results with several field campaigns for direct measurements of grain size distribution in the field and beyond preliminary results, we have also explored how topographic metrics (valley width, gradient, others) and the contribution of upstream area control the relative location of various sedimentary processes.

Characteristic dB values of SAR amplitude allowed us to identify surface types, which has aided the rapid mapping of a sedimentary process, but also to indirectly obtain regional grain-size maps. SAR backscatter intensity maps complemented with other remote sensing approaches can function as predictors of flow types within the ephemeral drainages of the Atacama Desert and will therefore aid mitigation strategies and understanding of arid landscapes to extreme precipitation events.

Fan-river interactions during extreme storm events: examples of El Huasco river, southern Atacama Desert

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High magnitude and low frequency extreme storm events have recently impacted the southernmost Atacama Desert. Considering that climate models at these latitudes suggest an increase in frequency of extreme storm events, coupling status monitoring of fan-river interactions represent an essential river management tool.

The efforts to simulate the spatial and temporal behavior of fans, under controlled boundary conditions, have been carried out with physical and numerical modellings. These studies aim to predict topographic effects of processes in fans under constant extrinsic variables by analyzing multi-temporal topographic data sets. The benefit of using experimental devices or numerical models instead of field examples is the rapid repeatability of the simulation of multiple debris flow surges to provide a long history of fan geomorphological changes. However, changes in connectivity between landforms ultimately determine the evolution of rivers under changing extrinsic variables. Unfortunately, due to the low-frequency nature of storms and the inaccessibility of arid landscapes there is a lack of detailed repeated-topography surveys that may assist in monitoring natural systems. The 24th March 2015 and 11st May 2017 storm events consequences in tributary-junction fans are outstanding field examples of how individual storms control fan geomorphology and sedimentology. High-resolution repeated topography, grain size analysis and detailed geomorphological mapping have been studied in the tributary-junction alluvial fans situated at El Huasco river valley (~29ºS). The results indicate that the deep incisions, due to entrenchment of the abandoned alluvial surfaces, resulted in the formation of new lobes on fan toes that, in many cases, blocked the main river or triggered river avulsion. The differences in sedimentology between the fans are a consequence of (i) different water to sediment ratios controlled by the amounts and intensity of rainfall during the events and, (ii) the characteristics of the catchments (e.g. net sediment storage, internal buffers, catchment gradient).
This approach could be used to monitor interactions between fans and the river in future storms that can help manage irrigation channel and water reservoirs. This information will be critical in a region where water resources are undergoing critical drought scenarios.

Geochemistry and microfacies study of travertine mounds from Slovakia

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Spring mound, a dome-shaped calcareous deposit surrounding a spring orifice, is a common travertine morphology in Slovakia. In this study, carbon, oxygen, and clumped isotope (Δ_{47}) composition of recently inactive travertine mounds from 9 locations (Santovka, Dudince, Čerin, Sliače, Liptovský Ján, Basenova, Vyšné Ružbachy, Gánovce, and Sivá brada) were measured to provide information about the origin of carbon, precipitation conditions, and paleotemperature. Petrographic analyses were used to identify microfacies types to reconstruct depositional environments.

Water discharge from the spring vent leads to the accretion of the mound ridges and formation of different travertine facies such as smooth slope, terraced slope, sub-horizontal layers of terrace pools and ponds, and subaerial deposits, where carbonate fabric is related to precipitation conditions of stagnant, fast or slow water flow. Based on petrographic descriptions, a variety of microfacies was identified, comprising several features such as crystalline crust, dendrites, coated grains, coated bubbles, reed molds, and rafts, formed by precipitation in situ, grains precipitated from thermal water or macrophytes coated by precipitated carbonates.

$\delta^{18}O$ and $\delta^{13}C$ values of travertine samples range from −12.2 to −5.8‰ (V-PDB) and 4.9 to 12.3‰ (V-PDB), respectively. $\delta^{13}C_{CO2}$ was calculated, providing values from −4.6 to 4.3‰. Carbon and oxygen data, as well as the calculated $\delta^{13}C_{CO2}$ values, imply isotopic signature typical for thermogene travertines, with thermal waters charged with isotopically heavy CO_2 of deep origin, possibly produced through thermometamorphic reactions. In Slovakia, mineral and thermal waters are mostly found in lowlands and in the Inner Carpathians depressions, which makes Triassic limestones and dolomites the most plausible carbon source.

Clumped isotope composition (Δ_{47}) of selected samples was measured, corresponding to temperature estimates ($T\Delta_{47}$) from 2°C to 32°C, using the calibration of Anderson *et al.* (2021). Comparing $T\Delta_{47}$ values with T°C measured in situ, Southern SK sites (Santovka, Dudince) are slightly higher than the present equivalents measured directly in thermal wells, while in Central SK (Čerin, Sliače, Liptovský Ján, Basenova) and Northern SK (Vyšné Ružbachy, Gánovce) paleotemperatures are slightly lower than temperatures measured in situ, except for one site (Sivá brada), that show higher values when compared to the temperatures measured nowadays.

Community engagement in safeguarding and salvaging the endangered rock art sites in Tanzania: a case from Ikungi District, Singida region (Central Tanzania)

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Located in the core of Tanzania, Singida region is characterized by an articulated landscape with plateaus, inselbergs, escarpments, and impressing rocky hills and Precambrian granite outcrops. These valuable features host a rich and variegated set of archaeological sites ranging from MSA-LSA and historic traditions, including a dense presence of rock art (paintings and engravings). Despite the ubiquitous presence of rock art and the characteristic landscape of Singida, only a few studies were carried out in the area. The research mainly focused in other areas, such as Manyara and Eyasi and Kondoa (declared a UNESCO World Heritage site in 2006 because of "its impressive collection of rock art"). Recent surveys, interviews and ethnographic inquiries revealed the potential of the area for the archaeological and geomorphological heritage. Lately, during our field surveys in 2022 on the eastern axis of the region (Ikungi District), we discovered more than 35 archaeological sites, typically with rock art (*Ngo'ngo a Bendera, Munini, Samamba, Gisamu, Makaho, Masaka* sites, between the others) with hunter-forager paintings such as naturalistic, stylized, schematic human and animal figures as well as geometric designs. The art stylistic motifs and subject matters painted by hunter-foragers recall the UNESCO heritage sites of Kondoa Irangi. However, the sites are facing major threats that need to be addressed, like "treasure hunting", looting and vandalism, or impact by stone quarries, as well as agricultural practices.

This paper presents some preliminary results of the actions adopted to mitigate these damages and eradicate the myth of treasure hunting on rock art painting sites through public archaeology and new management strategies. Furthermore, it calls for the salvage of the sites which are at risk of total disappearance due the encroachments by farmers and activities of the modern-day civilization.

Key Words: *Rock Art, Salvaging, Community Engagement, Conservation*

Biotic indicators of climate change in high altitude Tsoltak pro-glacial lake of Ladakh Range, NW Trans Himalaya, India

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Glaciers of the Ladakh Range are depleting at an accelerated rate due to their relatively small size and are typically restricted to high altitudes. The recession of the glaciers has resulted in the formation of pro-glacial lakes which occupy the higher elevations and the ones below are seen as remnant/palaeolakes now scattered over the abandoned moraines. In order to understand the ecology and productivity in a nutrient-starved cold desert ecosystem, the analysis of diatoms, along with pollen/spores, was carried out in sediment-water interface of stream, ephemeral pools, and Tsoltak pro-glacial lake along the Chang La pass region. In aquatic environments, diatoms are highly sensitive indicator organisms and their microfossils, deposited in lake sediments, can be used to infer environmental changes while pollen assemblage determines the vegetation pattern.

Our results suggest that the stream/main channel has a very less population of algal remains indicating that the water quality is not suitable for their growth. Maximal growth of algae is observed in ephemeral pools and lake which possess a more diverse ecosystem. The pools and lake create an oligo-mesotrophic environment with high primary productivity (diatoms like *Didymosphenia, Cymbella, Ghomphonema, and Pinnularia*; desmids like *Cosmarium, Staurastrum dilalatum* and *S. punctulatum*. Pollen assemblage constitutes the *Artemisia-Tanecetum*-Apiaceae-*Ephedra;* an assemblage of steppe vegetation indicating the availability of soil-moisture and soil-nitrogen fixation influenced by moist summers. The $\delta^{13}C$ estimates indicate dominance of C3 vegetation and reduced $\delta^{15}N$ indicates atmospheric Nitrogen fixation in the sediments. The aims of the present study are twofold: to determine the productivity of the pro-glacial lakes using modern-day surface samples and to compare this data with the past and to develop predictive models for future climate change. Thus a palaeolake section near the Tsoltak pro-glacial lake was studied which reveals the palaeoecology and palaeo-productivity since the last ~ 6300 cal year BP. The results show a strong correlation with similar diatom forms and pollen assemblage as compared to the modern-day surface sediments pointing towards similar climatic conditions that may have existed in the past.

A new geoheritage map overview for the Netherlands

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Geoheritage sites are essential to show landscape history and human-landscape interactions in the past to the general public. Increased awareness of geoheritage will lead to more effective use of geological features in heritage policies, the energy transition and water safety.
Even in a relatively flat as the Netherlands, relief is present, which is very informative on landscape evolution and the landscape history. Awareness on these topics is essential for implementing climate adaptation strategies in a smart way and furthermore offers chances for enhancing regional identity. Not all these landscape elements can be easily recognized by a laymen's eye, so how to bring this knowledge to landscape planners, developers and citizens?
We here present a new and accessible national map viewer on Dutch geoheritage, which will be embedded in map datasets on cultural heritage. Using site level descriptions with a scientific base, the role of the site in the evolution of the country is outlined.

Poster - sessions 9, 36, 42, 43, 46, 69, 70, 71, 84, 88, 92, 99, 102, 112, 138, 163, 169

New chronological developments on the Migration Period in Greater Poland based on palaeoecological data – preliminary results

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Paleoenvironmental reconstructions created in high chronological resolution can identify past anthropogenic impacts on the environment in detail. It is very helpful when archaeological recognition is inadequate, and thus, the reconstruction of chronology is severely limited. One such period in archaeology during the late Roman Period is the Migration Period (MP), dated in Poland to ca. 300-510 CE. The MP was characterized by climate deterioration and the mobility of people in Europe, initiated by the expansion of the steppe Huns tribe into Europe, which probably led to a massive displacement of the population.

A previous study from 36 published pollen data sets with robust chronologies from Polish Lowlands showed that after the MP forest expansion continued between 600-900 cal. CE, when the dawn of Slavic culture resulted in large-scale forest decline, especially in northwestern and north-central Poland.

However, in Greater Poland - where the first structures of Polish statehood were formed - little is known about settlements before 800 cal. CE. To fill this gap, we summarized preliminary results from four high temporal and chronological resolution pollen profiles (retrieved from peatlands and lakes) from areas where the first Slavic dynasty (Piast) created the State. This study aims to determine how the socioeconomic crisis during the MP before the appearance of Slavs in Greater Poland affected the local settlement (and whether was it continuous human activity or not) and how vegetation responded to this transition.

Preliminary results indicate the regeneration of oak-hornbeam forests shortly after the MP (ca. 360–510 CE). The hornbeam was gradually selectively logged from as early as 600 cal. CE, which proportion in forests decreased significantly until 900 cal. CE. In the Greater Poland region, it was the time of the first state structures establishment. In our data, this period corresponds to increased human impact indicated by an increase in the percentage of various pollen types of cereals and ruderals. This work constitutes the first step in exploring high-resolution paleoenvironmental changes (with a special focus on human impact) during the Migration Period in Greater Poland.

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Treasuring the inevitable: soil loss as a tool for understanding archaeo-environmental palimpsests. A case study from Mahal Teglinos (Kassala, Eastern Sudan)

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Damage caused by erosion on soils and landscapes is a foremost matter that is recurrently addressed by scholars belonging to different fields and working in diverse regions characterized by highly dynamic environments. All parts agree that sheet, linear, and gully erosion must be appointed as one of the most prominent manifestations of land degradation in all environments where intensive rainfall occurs. In arid lands, erosion-related loss of archaeological record - which is inherently embedded within the younger and most delicate geological strata and pedological bodies - represents a setback for researchers and local communities alike. Although mitigation techniques and conservation policies have been proposed, it is general consensus that, in the short and medium run, and where site remoteness represents an infrastructural limitation, soil loss cannot be avoided. Nevertheless, the dismantling processes not only represent an active manifestation of the morphogenetic and environmental history of sites and regions, but are also key to access buried extensive archaeological and environmental palimpsests that would be otherwise approachable only by means of test trenching and coring.
A noteworthy case-study is represented by the Sahelian site of Mahal Teglinos (Kassala, Eastern Sudan), a secluded small valley hosting rich Late Quaternary archaeological and pedosedimentary records. Therein, despite the hot semiarid regional climate (BSh), hydric erosion acting on delicate sediments is today the main driver of soil displacement and loss. Nonetheless, the erosional process unveiled buried and concealed features composing a thick natural palimpsest that testifies a highly dynamic succession of morphogenetic events, telling a story of Holocene climate changes and human adaptation. Stratigraphic correlation and archaeological evidence also suggest that the erosional surface processes started during the first millennium BCE, making the missing soil an effective feature of the archaeo-environmental palimpsest. Nonetheless, erosion is currently accelerating due to weather anomalies and climate change, threatening the remaining pristine contexts. This work represents a call for action in taking advantage of naturally exposed stratigraphy prior to its total loss, especially in remote and understudied areas where sites are hardly accessible and information yield may be ultimately favoured by undertaking regional-scale surveys rather than single-site deep excavation.

Lake record of black carbon from southern Sweden reveals increased flux in the early 18th century

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Black carbon (BC) is produced by incomplete combustion of organic matter and fossil fuels. The BC particles consist of highly condensed and aromatic carbon compounds with high resistance to degradation and are thus important for the long-term carbon storage in soils and sediments. BC particles are also part of the particulate pollution with severe health consequences.

Here we present BC concentrations and accumulation rates in the sediments of a small lake (Odensjön) in southern Sweden. The lake is situated at 60 m a.s.l. on a bedrock ridge, has a diameter of app. 150 m and a maximum water depth of 20 m. The lake is the southernmost site in Sweden with varved sediments. We have retrieved an 89 cm long freeze core and established a chronology based on ^{210}Pb, ^{14}C and varve counting. BC was quantified using the thermal chemical oxidation method (CTO375).

Our BC record has relatively high maximum concentrations (>0.92%) and shows an early increase in concentration and accumulation rate starting around CE1700. This early rise in BC accumulation rate took place around 150 years before the main phase of industrialisation in Sweden and was likely an effect of increasing population and small-scale industrialisation in the region. The BC accumulation rate continued to increase steadily until an accentuated rise in the mid-20th century. This further increase was likely a direct effect of the elevated fossil fuel consumption after CE1950. Intriguingly, the BC accumulation rate increased during the 1990s and has remained high. To further explore the history and sources of the BC pollution, we will measure the ^{14}C content of the BC fraction to differentiate between BC derived from burning of biomass and fossil fuels, respectively.

Palaeolithic Technosols as indicators of early inception of the Anthropocene at the Upper Palaeolithic sites Kostenki 14 and 17, East European Plain

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Neolithic revolution is often considered an onset of significant anthropogenic impact on ecosystems, i.e., the onset of the Anthropocene. The substantial advancement in human-nature interaction on the verge of Neolithic revolution could have resulted in the appearance of new soil type, such as Technosols. Recent palaeobotanical studies provided evidence of niche construction during Upper Palaeolithic in Europe and Middle Palaeolithic in Eastern Africa, which triggered the discussion of earlier onset of the Anthropocene. Since “Soil is the mirror of landscapes” and Technosols are evidence of the significant local anthropogenic impact, they might serve as indicators of niche construction, thus, the inception of the Anthropocene.

New palaeopedogenic data obtained at the Upper Palaeolithic sites Kostenki 14 and 17 imply the existence of Palaeolithic Technosols. Cultural layers are often found within palaeosol horizons. Despite weak development of the studied palaeosols, their “soil memory” contains significant palaeoecological information, whose interpretation is yet unclear. Along with the versions of its natural genesis, the anthropogenic version has been suggested. The combination of magnetic and biogeochemical (FTIR, biomarkers) analyses indicates the pyrogenic effect on palaeosols and spatial variability of soil properties within the cultural layer. Combined with abundance of artefacts observed at macro and micro scales, this demonstrates the anthropogenic genesis of the discussed palaeosols.

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The Antropocene signature in Mediterranean endorreic Iberian karstic lakes: Zoñar (Andalucia) and Estanya (Aragón)

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The Anthropocene poses particular challenges in regions with Mediterranean climates as they are characterized by both a long history of human occupation, a strong seasonality of hydrological regimes and an annual water deficit. Predicting the impacts of future climate change in Mediterranean watersheds requires detailed knowledge of baseline watershed responses to past climate variability and assessing the magnitude of past human intervention in the landscape and the ecosystems. In this contribution we summarize the depositional evolution of two lake – watershed systems located in the Ebro and Guadalquivir Basins in region with a long history of human activities since the Neolithic. A multiproxy analysis of the sedimentary sequences of both lakes has been carried out, based on the study of facies, elemental geochemistry and the study of the isotopic signature of organic and inorganic components. In addition, we present the results of water and sediment monitoring until present date, which will help to better understand the mechanisms of these lakes in the past. The > 20 ka long Estanya sequence (Pyrenean Range, 42.027474, 0.530450>) show a rapid increased in sedimentation rate since Roman times and particularly since 10th century. Zoñar Lake (Guadalquivir Basin, 37.482889, -4.690522) illustrates large hydrological changes during the last 4000 years, and a strong impact in the watershed during Roman and Medieval times. In both cases, agricultural changes during the last century, and particularly since mid-20th have greatly altered the ecosystem with increased sedimentation rates, change in the depositional environment and oxygenation conditions. The past global change reconstructions will help to develop strategies for mitigation and adaptation to recent global changes in Mediterranean regions prone to long-term droughts and subjected to intense use of the resources.

Plutonium isotope records in marine sediments from the southern Gulf of Mexico

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A suite of sediment cores collected from the continental shelf and upper slope region of the GoM consistently showed $^{240}Pu/^{239}Pu$ ratios consistent with global fallout Pu for this tropical region. In the continental shelf and upper slope regions, higher particle concentrations close to the margins favor significant scavenging and removal of Pu from the water column; in contrast with the deep-sea cores that show low $^{240}Pu/^{239}Pu$ ratios (0.07 – 0.13) and a much lower Pu inventory (< 7 Bq m^{-2}) implying a small fraction of the expected global fallout inventory has reached into the lower slopes and abyssal plain of the GoM. The low Pu ratios indicate that Nevada tests fallout was an important source of Pu to deep-sea sediments, and that this source was likely more efficiently removed from the water column than global fallout Pu. Analysis of Pu isotopes in two sediment traps from the upper slope regions show $^{240}Pu/^{239}Pu$ ratios comparable to the ones observed in the global fallout, indicating that global fallout Pu is currently the main source of Pu in the water column particles. These results imply that a significant fraction of global fallout Pu must still be present; either in a dissolved phase, or as biologically recycled material in the water column, or scavenged on the shelf and shelf break.

TerrACE: European Archaeology and Culture from Agricultural Terraces and Implications for Heritage and Agricultural Sustainability

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Agricultural terracing is the greatest human alteration to the earths surface prior to the growth of cities and can be regarded as a hallmark of the Anthropocene. Despite this we have a very limited understanding of their chronology and archaeology and only some understanding of their geomorphological implications. This is now a serious problem as agricultural terraces (and lynchets) are under threat from mechanised agriculture and rural depopulation worldwide, yet it is believed that they are both sustainable and resilient if kept in continuous use and maintained. We present here the results from a Europe-wide study of terraces and lynchets from Norway in the north to Crete in the south. We brought to the question an integrated set of novel techniques (pOSL/pRSL, sedaDNA), along with established techniques for terrace mapping (UAV-SfM, TLS), dating (OSL, 14C) and palaeoenvironmental analysis (phytoliths, pollen, soil micromorphology, pXRF, FTIR). This data is nested into the digital elevation models (DEMs) derived from both UAV structure from motion (UAV-SfM) and terrestrial laser scanning (TLS). We have a chronology which spans from the mid-Holocene (Mid Bronze Age, c. 3500 BP) to the post-medieval period (<300 years BP). This has landscape heritage implications as well as showing how sustainable many ancient systems are. We also show how supplementing chronometric information with pOSL, pXRF and soil micromorphology can be used to indicate complex terrace history. Past crops are revealed by both pollen and phytoliths and we also show that sedaDNA is preserved in terraces from most of the regions, except the most arid. In some cases the crops revealed go beyond cereals (e.g. hops, vines, horticulture) and provide direct data on the nutritional and cultural contributions of terrace agriculture to these communities. This is the first use of sedaDNA for such ancient sites and, although there are significant problems of interpretation of taphonomy and bioturbation, extrinsic authentication suggests that they have high future potential. During the project innovations have been made in several areas including the fusion and modelling of soil volumes from UAV-SfM with TLS and the modelling of complex soil history and land use.

Mollic or anthromollic? – Phaeozems at the Bronze Age site of Toboliu (Romania)

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The Bronze Age tell of Toboliu (*Dâmbu Zănăcanului* Bihor County, Romania) and its outer settlement is located at the eastern margin of the Great Hungarian Plain, between the Crișul Repede floodplain in the north and the high plain of Miersig in the south. Today, the area is intensively used for agriculture. In the clayey loess Phaeoems have been developed, which are characterized by a mollic horizon enriched in organic matter and homogenized by bioturbation. Geomagnetic surveys, core drillings and excavations carried out by an interdisciplinary team indicate that the soils have been markedly modified by settlement activity, agriculture, gardening and animal husbandry. We assume that their signature is still stored in the soil. Geoarchaeological (micromorphological analyses, geochemical- und physical analyses, dating methods etc.) and biochemical methods (phenols, lipids, black carbon etc.) will be used to clarify the genesis of these dark brownish soils. In order to determine the degree of human influence - to differentiate Phaeozems from anthromollic Phaeozems and Anthrosols, soils from different parts of the Bronze Age settlement site and its surroundings will be analysed.

Recent environmental changes in the Yunnan–Guizhou Plateau inferred from organic geochemical records from the sediments of Fuxian Lake

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During the past century, many lacustrine environments have changed substantially at the ecosystem level as a result of anthropogenic activities. In this study, the distributions of n-alkane homologues, carbon isotopes ($\delta^{13}C_{org}$), organic carbon, and the C/N atomic ratio in two sediment cores from Fuxian Lake (Yunnan, southwest China) are used to elucidate the anthropogenic impacts on this deep, oligotrophic, freshwater lake. The carbon preference index (CPI) of long-chain components, average chain length (ACL), proportion of aquatic macrophytes (Paq), and terrigenous/aquatic ratios (TAR) show different temporal patterns that reflect variations in biological production. Notably the n-alkane homologues are shown to be more sensitive to environmental changes than $\delta^{13}C_{org}$ and the C/N ratio. Prior to the 1950s, minor variations in the sedimentary geochemical record were likely caused by climate changes and they represent a natural stage of lake evolution. The onset of cultural eutrophication in Fuxian Lake occurred in the 1950s, when the n-alkane proxies collectively exhibit high-amplitude fluctuations but overall decreasing trends that coincided with population growth and related increases in land-use pressure. In the 21st century, Fuxian Lake has become even more eutrophic in response to human activities, as indicated by sharp increases in C/N ratio, Paq, $\delta^{13}C_{org}$, ACL, CPI, and TAR. Our findings provide robust molecular sedimentary evidence confirming that the environmental evolution of lakes in the Yunnan–Guizhou Plateau over the past century was closely associated with enhanced anthropogenic activities.

The rise of pyrometallurgy and 7000 years of continuous anthropogenic metal pollution in southeastern Europe

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Archaeological data document early cultural traits in southeastern Europe linked to ancient metalworking by 5500 years BCE, but lack of data precluded a precise understanding of their long-term environmental impact. Here we report geochemical and isotopic data from several Carpathian peat profiles showing evidence of lead (Pb) excess denoting anthropogenic metal pollution already by ca. 5200-4300 BCE. Our find directly corroborates the archaeological evidence, as the dazzling array of early metal artifacts considerably exceeds evidence from elsewhere making this a phenomenon largely exclusive to southeastern Europe. Using also Pb isotopic constraints we conclude that the rise in Pb by ca. 5200-4300 BCE represents a direct record of environmental pollution during this era of primitive but widespread smelting and proto-metallurgical experimentation in southeastern Europe. We also observe another period of anthropogenic Pb pollution during the Late Copper/Early Bronze Age □3,600 years BCE, to date one of the earliest such evidence documented in European environmental records. By 1000 BCE the environmental signal of excess Pb became ubiquitous in southeastern Europe, peaking during the Iron Age and the Roman period. A steady, almost linear increase in Pb concentration after 600 BCE, until ca. 700 CE is observed, documenting the development in both sophistication and extent of southeastern European metallurgical activity throughout Antiquity and the Roman period. A sustained medieval Pb pollution spanning 10th to 16th centuries AD reached pollution levels and a Pb flux comparable to the modern period.
Our reconstruction of environmental pollution contrasts and complements evidence from western Europe. We advocate this reflects regional variability in metal pollution output linked to developments attained by the different European societies for last millennia. Our results add crucial evidence to the long-range and long-lasting legacy cast upon the environment by past metal processing in Europe already from the Late Neolithic, c. 7000 years ago.

Some geomorphological perspective on the (paleo-)Anthropocene: early human overprint on landforms

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The current debate on the concept of Anthropocene is mostly dedicated to the definition of the formal chronostratigraphic position of the onset of this phase of the history of planet Earth. More recently, alternative hypotheses have been postulated to overcome this issue, and several authors proposed to define the Anthropocene as an event rather then a formal geological epoch. Beside the debate on the formal definition of the Anthropocene epoch along the geological time scale, emerging evidence suggests a pristine and long-lasting human overprint on natural ecosystems and surface processes. Since at least the Holocene, humans have intensely interfered with geomorphological processes; they accelerated and/or decelerated the rate and efficiency of certain natural geomorphological processes and contributed to activate and/or deactivate other processes. At the meantime, such interference on natural surface processes resulted in increased vulnerability of the human environment to paroxysmal events. From a different perspective, humans contributed to the destruction of natural landforms directly, for instance with building and quarrying activities, or indirectly, enhancing erosion. But when did humans start altering pristine landforms and influencing permanently geomorphic processes? The geoarchaeological record offers new evidence reporting on permanent human agency on geomorphological processes, thus further sparking debate about the onset of the Anthropocene. In this contribution, we will discuss the meaning of the term “Anthropocene” and its relevance for the possible early onset of human agency on geoarchaeological and geomorphological processes.

Human Traces: a PAGES working group synthesizing sedimentary records of human 'footprints'

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The Human Traces working group is developing tools and knowledge to gain a better global perspective of human impacts over the (paleo-) Anthropocene using sedimentary archives. Sediments from lakes, ponds, wetlands and coasts are reliable stratigraphic archives of natural variability and human-induced changes in the environment. The principal aim of this PAGES working group is to elaborate tools and reviews to help synthesize information based on data gathered from aquatic sedimentary archives, that will lead us to a better understanding of the timing, nature and magnitude of human impacts on the environment at various spatial and temporal scales. Indeed, the human footprint on the natural environment can vary in origin and proportion in various regions of the world through time. This is due to a multitude of factors, including the timing and direction of human migrations and the state of technological development. There is still a paucity of long-term environmental regional data and a global synthesis of human impacts on aquatic ecosystems is lacking. We are therefore working on creating a global database of sedimentary records of human traces on the environment. In this presentation, we will describe the scientific activities and projected outcomes of the working group, which has been running since 2021 and will likely continue for the next 3 years.

Written in Stones: Man and environment relationship in Indian archaeological records

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Homonin species have been utilising natural resources before they even became fully developed into anatomically Homo-sapien-sapiens. In India, we begin to see the earliest evidence of Homonin around 1.5 Ma in the form of stone tools. Initially, exploiting rocks as raw materials for producing tools to now altering the eco-system altogether. In this paper, I aim to discuss 5 independent archaeological records from different time periods and from different regions of India that provide evidence of Man and environment relationship. The bullet points of evidence are as follows-

1. Inscription that mention about construction and repair of dam
2. Inscription that mention about a royal kitchen and food (particularly meat)
3. Baolis (stepwells) for storing water in western India
4. *Navle* for storing water in central Himalayas
5. Inscription that mention about multiple floods in river Narmada

The aim of the paper is to discuss various archaeological and ethnographic records that may help us in reconstructing man and environment relationship in the past and present.

The geo-environmental characterization of contaminated coastal sites as tool for the analysis of human footprint on marine and coastal environments.

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In Italy, several coastal sites are affected by intense modifications and diffuse environmental pollution due to the strong industrialisation and urbanisation processes that have taken place since the second half of the XIX century. Despite its remarkable geomorphological, ecological, and touristic value, the coastal sector of the Apulia region (Southern Italy) hosts three of the main contaminated Italian sites (Sites of National Interest), for which urgent environmental remediation and reclamation actions are required. In this study, the assessment of direct and indirect impacts of past and present anthropogenic activities in the Apulian coastal sites is carried out by coupling geophysical, sedimentological, and chemical analysis performed in the framework of several characterization activities founded in the last years. The study is aimed at highlighting the main criticalities affecting the investigated coastal sectors (e.g., chemical pollution, anthropogenic traces on the sea floor, litter distribution) and how the multidisciplinary investigation can support the identification of tailored management actions for the environmental reclamation as well as for the evaluation of the best characterization procedures.

An interdisciplinary approach to understanding resilient woodlands in an Anthropocene landscape

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In the heavily human-modified landscape of the English Midlands, UK, Ancient Semi-Natural Woodland sites have undergone extensive human disturbance for millennia, including severe modification such as clear-felling in the 20th century. Here we use an interdisciplinary approach to examine the long history of disturbance and identify patterns of ecosystem resilience to change, taking the area of East Leicestershire and Rutland as our case study area.
Through the integration of information from the fossil pollen record (early Holocene to present), place-name evidence of past vegetation cover (extending back to medieval times), LiDAR data, and recent botanical surveys, our methodology aims to identify regions that have maintained long-term, stable woodland cover and to elucidate how ecosystems have recovered after natural environmental or anthropogenic disturbances. We aim to develop an integrated spatiotemporal framework that quantifies the resilience of woodland ecosystems to change, and to use this as a dataset to inform the stewardship of Anthropocene landscapes into the future. Though we apply this in a UK-setting, such interdisciplinary approaches have likely utility in a range of woodland/forest contexts.

The biogeographical history of Carpinus betulus in the Iberian Peninsula

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The Iberian Peninsula is part of the Mediterranean hotspot and displays a high rate of endemism involving Mediterranean, Eurosiberian, Alpine, Boreal, Macaronesian and North African plant species. Arctotertiary and Lauroid floras reach Mediterranean mountains of the peninsula where appear to have refuged during the late Quaternary. In some cases, the remnants of past distributions are limited in number and range. This is the case of *Carpinus betulus* (hornbeam), a boreal species widely extended nowadays in Northern Europe but showing only three small populations in Iberia. Here we deal with this apparent anomaly and question (i) whether the distribution of hornbeam in the Iberian Peninsula was always so restricted, (ii) where was this species present during various phases of the Quaternary, (iii) why was it more widespread in the past within the study region, and (iv) which were the climatic and/or anthropic pressures exerted to provoke populational depletion upto the current situation. To this goal, we review pollen records of *Carpinus betulus* in the Iberian Peninsula during the Pleistocene and Holocene, and report of study of the species´pollen rain, and its significance in terms of population size and dispersive capacity.

New records of terrestrial and freshwater mollusc species for the Quaternary of Uruguay

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Few studies about the Quaternary continental molluscs of Uruguay had been published over the last decades, despite the high occurrence of this group in many of the Pleistocene outcrops of the country, all of them better known for their classic Ice Age mammal assemblages. In order to overcome this situation, new studies had been conducted, collecting new samples in 23 localities belonging to two lithostratigraphic units, the Sopas Formation (~45,000 – ~13,000 AMS ^{14}C calBP) from northern Uruguay (12 localities), and the Dolores Formation (~27,000 -~11,000 AMS ^{14}C calBP) from the West and South-West (11 localities). The species of continental molluscs recorded in the Quaternary of Uruguay are included in the families Sphaeriidae, Cyrenidae, Mycetopodidae, Hyriidae (freshwater bivalves); Ampullariidae, Cochliopidae, Tateidae, Chilinidae, Physidae, Planorbidae (freshwater gastropods); Scolodontidae, Succineidae, Charopidae and Bulimulidae (terrestrial gastropods). As a result of these new samplings, the Sopas Formation molluscs species account raised from 20 to 29 species and the Dolores Formation from six to 29 species. Seventeen of those species are new records for the Quaternary of Uruguay: the freshwater bivalves *Afropisidium sterkianum* and *Pisidium vile*; the freshwater gastropods *Pomacea lineata*, *Asolene platae, A. spixii, Stenophysa marmorata, Drepanotrema heloicum, D. kermatoides, Heleobia robusta, Potamolithus catharinae, Hebetancylus* cf. *H. moricandi* and *Uncancylus* cf. *U. concentricus*; and the terrestrial gastropods *Miradiscops brasiliensis, Zylchogira costellata, Omalonyx convexus, Succinea meridionalis* and *Plagiodontes dentatus.* Regarding all the species records (new and old ones), for the Sopas Formation two bivalves, five freshwater gastropods and a new terrestrial gastropod were added; while for the Dolores Formation four new bivalves, 14 new freshwater gastropods and five new terrestrial gastropods were added. The Dolores Formation clearly was the most understudied unit until now, increasing its biodiversity in 23 species. These new records of freshwater and terrestrial gastropods, not only increase the biodiversity of the continental molluscs of the Late Pleistocene of Uruguay, it also increases the knowledge and biogeographical range for Quaternary continental molluscs of the region.

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Anthropogenic alteration of the marine fossil record

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The youngest fossil record is an indispensable source of data on long-term human impact on marine ecosystems. However, human actions alter not only marine communities and their habitats but also sedimentary and biotic processes controlling the formation of the stratigraphic archives recording those changes. Anthropogenic drivers can modify sedimentation rates, depth and intensity of sediment mixing, and preservation potential of skeletal remains. These drivers are diverse and include, among others, changes sediment fluxes due to reshaping of alluvial and coastal landscapes, seabed disturbance by bottom trawling and ship traffic, ocean acidification and anoxia, removal of native species, and introduction of invasive ecosystem engineers. These physical, geochemical and biological disturbances can affect the temporal resolution of the youngest fossil record and shape the stratigraphic expression of human-driven ecosystem shifts. The resulting taphonomic and stratigraphic signatures can pinpoint historical changes in ecosystem functioning, as many key ecosystem processes also control the burial and preservation of skeletal remains. At the same time, however, systematic changes in the quality of the record induced by human actions are a challenge for environmental, paleoecological and paleoclimatic reconstructions based on the data from sediment cores and surface death assemblages. Understanding complex feedbacks between human impacts on the ecosystem processes and their preservation in the marine stratigraphic record is thus crucial for correct interpretation of geohistorical archives that document the ongoing anthropogenic transformation of the oceans.

Radiocarbon dates shed light on the extinction chronology of endemic rodents from the Tiburon Peninsula, Haiti

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The island of Hispaniola has been considered the center of Caribbean rodent biodiversity. Until recently, it was home to 10-12 endemic species, but today, just one endemic species is present (*Plagiodontia aedium*, Cuvier's hutia). The timing of rodent species loss across the Caribbean, and on Hispaniola specifically, is poorly constrained, which makes the identification of extinction triggers challenging. Both human activities and climate have been implicated. We radiocarbon dated eight rodent specimens from Trouing Jérémie #5, a paleontologically-rich sinkhole on the Tiburon Peninsula, in southwestern Haiti and combined these with two recently published dates for the site. This combined sample included seven endemic extinct taxa (*Plagiodontia ipnaeum*, *Brotomys voratus*, *Isolobodon montanus, I. portoricensis*, *Hexolobodon phenax*, and *Rhizoplagiodontia lemkei*) and introduced murid *Rattus*. Radiocarbon dates for these rodents demonstrate that bone accumulations at Trouing Jérémie #5 span the Holocene. The single specimen for the largest species, *P. ipnaeum* (5.3-5.9 kg), dates to the very early Holocene (median calibrated age=11,091 calendar years before present; Cal BP). *Hexolobodon phenax* (3.2-3.3 kg), *I. montanus* (1.5-3.1 kg) and *R. lemkei* (1.3-2.0 kg) date to the mid-Holocene (6297-7050 Cal BP), *B. voratus* (ca. 0.4 kg) dates to the late-Holocene (3122 Cal BP), and the two dates for *I. portoricencis* (1.0-1.4 kg) span the mid- to late-Holocene (5164 and 1659 Call BP). These dates confirm that the sampled extinct taxa were all present into the Holocene, and several coexisted with humans, who arrived on the island ca. 6000 years ago (*I. portoricensis and B. voratus* appear to have overlapped with humans for several thousand years). However, we do not know if any endemic rodents were still present when Europeans arrived in the late 15th and early 16th centuries. Both murid *Rattus* specimens date to the last few centuries (307 and 502 Cal BP), suggesting that rats likely spread rapidly on Hispaniola after introduction. Additional radiocarbon dates from Trouing Jérémie #5 and other sites in the Tiburon peninsula will help clarify regional extirpation patterns and provide a chronological framework for examining ecological change.

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Birds and Quaternary climate changes: avifaunal shifts on the Eastern Adriatic coast, Croatia

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The Mediterranean region is very rich in avifauna, with Croatia being one of the richest countries in Europe in terms of biodiversity. This is the result of its specific geographic position in-between Mediterranean, Alpine and Continental biogeographic regions, and its geomorphology, especially its karstic region. Here we present Eastern Adriatic Late Pleistocene and Holocene bird assemblages (without small passerines) found at sites with abundant bird remains. A total of 60 species were identified in the avifaunal assemblages from the sites of Marlera I, Šandalja II, Ljubićeva pećina and Vela spila, while the recent list includes 168 species. The relative frequency of different faunal types was temporally (MIS 3 vs. MIS 2 vs. MIS 1) and spatially (NW vs. SE Adriatic) compared. The general composition of the Late Pleistocene and Early Holocene avifaunal assemblages is broadly similar to that found today. Species of Palearctic faunal types dominate, followed by Holarctic species. A few of the species identified in Late Pleistocene assemblages are of Arctic and Siberian faunal elements that today live on the mountains or in Northern Europe. Species that belong to the Arctic faunal type were present at both parts of the Adriatic, while those of the Siberian faunal type were present only on the northwestern Adriatic. Arctic and Siberian species recorded along the coast today are passage migrants or winter visitors, in contrast to the Late Pleistocene assemblages when species of those faunal types were residents. The Early Holocene avifauna consisted of extant bird taxa of the eastern Adriatic coast, whether present as seasonal migrants or year-round residents. Recent avifauna is enriched with Indo-African, Ethiopian, Mongolian-Tibetan and North Atlantic species compared to the Late Pleistocene and Early Holocene assemblages where representatives of those faunal types were not recorded. There is thus a slight temporal trend in taxonomic composition from species adapted to temperate-boreal climates during the Pleistocene to those adapted to temperate-Mediterranean climates during the Holocene. Late Pleistocene avifauna was enriched by northern species without a significant loss of species adapted to more temperate conditions, which further confirms the eastern Adriatic coast as one of glacial refugia.

A Conservation Paleobiology approach over an endangered freshwater bivalve genus from South America

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The extant South American genus of freshwater bivalve *Cyanocyclas* is recorded for the Quaternary of Uruguay mainly in the Sopas Formation (Late Pleistocene – MIS3) and in only one locality of the Dolores Formation (Late Pleistocene – Early Holocene). When present, it occurs in a large number of specimens. It is mainly recorded in coarse to sandy strata that usually are located over coarser strata with records of large bivalves, such as representatives of the genus *Diplodon.* The historical record *Cyanocyclas* indicates that it was present in rivers and streams throughout the territory. The geopaleontological analysis and the historical record indicate that the species normally inhabited coarse to sandy, firm substrates, and occasionally soft substrates. Since the 1990s and to the present, the alien species *Corbicula fluminea* has gradually invaded the freshwater systems of South America, including Uruguay. The Asiatic species belong to the same family as the autochthonous genus, Cyrenidae, and has successfully displaced the *Cyanocyclas* species from their habitats. Now, *Cyanocyclas* can hardly be found in most of the localities where they originally were recorded. Mainly, it can now be found in soft, fine sand to pelitic bottoms, rather than the consolidated sandy substrates where historically it inhabited the most. Some authors indicate that the substrate change can be explained as an adaptation to colonize habitats that are harder to colonize by the invader species, since siphons in *Cyanocyclas* are larger than in *Corbicula,* allowing them to better adapt to soft, fine substrates. The paleontological and historical data corroborate that *Cyanocyclas* tend to inhabit mostly firm substrates (as *Corbicula*), but it was capable of inhabiting soft bottoms as well. Therefore, although this is only the first approach in the Conservation studies for this genus, it is clear that the inferences of other authors about the causes of the decline in *Cyanocyclas* populations would be correct. The environment in which the autochthonous species inhabited, both in the historical record and in the fossil record, indicates that the species prefer firm substrate environments, where today we find the invasive species, being the autochthonous species displaced to softer substrates.

The Raigón Formation (Plio-Pleistocene of Uruguay), a disruption in space and time?

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The Raigón Formation, deposited in the Santa Lucía Basin, southern Uruguay, was defined by Goso and Bossi in 1966. Previously Francis and Mones defined the San José Formation, unit which is nowadays considered the basal member of the Raigón Formation. It is characterized by gray-greenish sandstones and conglomerates of fluvial origin at the base, changing to fine clayish sandstones with carbonate septi intercalated with loess at the top. Sterile when first defined, the San José "Formation" yield it first fossil right away, a fossil rodent, *Cardiatherium talicei* Francis and Mones 1965. Prior to the aforementioned formal stratigraphic definitions Kraglievich and Castellanos, among others, described fossils that today can be assigned to the Raigón Formation. As this unit continued to be studied, a very particular fauna was unveiled. Posteriorly to the description of *C. talicei* new taxa integrated to a particular faunal association where mammals abound were discovered. This association is characterized by endemic species, others representatives of the South American Cenozoic and others of North American origin. Endemic taxa include the large rodent *Josephopartigasia* (Francis & Mones 1966) Mones 2007, the proterotherid *Uruguayodon alius* Corona, Perea & Ubilla, 2019, and the toxodont *Charruatoxodon uruguayensis* Ferrero, Schmidt, Pérez-García, Perea and Ribeiro, 2022, among others. *Trigodon* Ameghinio, 1882, and *Devincenzia* Kraglievich, 1932, among others, are present in the Raigón Formation and the Neogene of Argentina. Finally, the striking presence of cf. *Xenosmilus* Martin, Babiarz, Naples & B Hearst, 2000, together with other clearly Quaternary taxa such as *Catonyx tarijensis* (Ameghino), 1891, and *Plaxhaplous* Ameghino , 1884 in this unit reveals a very particular faunal composition that can be interpreted in different ways. This work will present a synthesis of the biostratigraphy of the Raigón Formation, including new paleontological data, and OSL datings from the top of that unit. Through it, a Late Pliocene-Chibanian lapse is proposed for its deposition, with a particular fauna that could be the result of recurrent episodes of geographic isolation, climatic fluctuations, and exclusive fossil record during the origins of the La Plata River Basin. Partial support by project C108-347 CSIC/UdelaR, PEDECIBA, and ANII, Uruguay.

When rhodolith beds are heterogeneous, who can help? Studying the associated mollusk thanatocoenoses to unravel (paleo)environment

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Rhodoliths are marine biogenic carbonate nodules that often form extensive beds on the shelf. They increase the complexity of the seafloor that translates in supporting high biodiversity, which led them to be included in several international programs for sustainable management and conservation. Although several studies focused on rhodoliths, it is still not clear how the combination of biotic and abiotic factors controls the different rhodolith morphostructures that frequently form heterogeneous beds. Moreover, they have a consistent fossil record at least for the whole Cenozoic that is often hard to be interpreted because of the scarce knowledge of rhodolith bed dynamic and its taphonomic bias.

But how much (paleo)biological and (paleo)environmental information is preserved within rhodolith beds?

Quaternary studies offers the possibility to study rhodolith beds as they are now, and then use these observations to better interpret their fossil analogues, and trace changes through time. Therefore, to answer this question, we focus on the study of present day rhodolith beds *plus* associated mollusks, together with data on grain-size and environment (temperature, current). Mollusks represent a tool for tracing hidden diversities among heterogeneous rhodolith beds, because: 1) their ecological and environmental requirements are well known and 2) they show a strict fidelity to specific environmental conditions. This work reports the results of the study of three heterogeneous rhodolith beds from the Tyrrhenian Sea (Italy), where rhodoliths show different shape and morphotype, but often combine in having heterogeneous beds. Mollusk thanatocoenoses combined with rhodolith morphometry, grain-size and environmental data, reveal that such beds are characterized by limited differences in associated edaphic factors which however determine the occurrence of "sentinel" mollusk species that characterize exclusively different rhodolith beds (*Alvania cimicoides*, *Goodallia triangularis*, *Dosinia exoleta*, *Tetrarca tetragona*, *Limatula subauriculata*, *Clausinella fasciata*).

Vegetation changes in the Osumi Peninsula, southern Japan before and after the Kikai Akahoya eruption, inferred from phytolith records

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The Kikai Akahoya eruption occurred at 7.3 ka in the Kikai caldera, located approximately 50 km southwest of Kyushu Island, Japan. Southern Kyushu Island's ecosystems were devastated by the Kikai Akahoya tephra, particularly the pyroclastic flows (Koya pyroclastic flow). We examined phytolith assemblages in paleosols in the plateau and mountain areas in the Osumi Peninsula in the southernmost part of Kyushu Island to assess the influence of the pyroclastic flows on vegetation. The appearance of broad-leaved arboreal phytoliths characterized the phytolith assemblages in the paleosols under Kikai Akahoya tephra, suggesting that the evergreen broad-leaved forests were distributed in the study region before the eruption. In the plateau area, where the pyroclastic flows were more thickly distributed, the phytolith assemblages in the paleosol between the Kikai Akahoya tephra and Ikedako tephra (6.4 ka) were characterized by the predominance of Andropogoneae (*Miscanthus*)-type phytoliths and the absence of arboreal phytoliths. In the mountain areas, evergreen broad-leaved arboreal phytoliths were observed in the paleosol under the Ikedako tephra, despite Andropogoneae (*Miscanthus*)-type phytoliths being more common in the paleosol above the Kikai Akahoya tephra. These results suggest that the vegetation transition after the eruption in the plateau and mountain areas differed in the study region. The evergreen broad-leaved forests were destroyed, establishing Andropogoneae (*Miscanthus*) grasslands in the study region after the eruption. The evergreen broad-leaved forests hardly recovered even 900 years after the eruption in the plateau area. In contrast, the evergreen broad-leaved forests recovered within 900 years in the mountain area. The little pyroclastic flow reaching the areas would have left some untouched forest sites as refugia, and the forest would have recovered from the refugia.

Refuge areas and postglacial dynamics of Arbutus in Western Eurasia

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Arbutus is a genus belonging to the Ericaceae family with four species currently recorded in the Old World, according to outputs of phylogeny and taxonomy. They are centered in the Mediterranean Basin, scatter along the Atlantic coast, and reach Macaronesia, being one of the most important representatives of the Mediterranean broadleaved evergreen element. We investigate the present and past distribution of *Arbutus* to reach a better understanding of the drivers and constraints of its biological requirements and its postglacial dynamics.

We collected, compared, and screened a body of information based on the floristic and geobotanical historical literature, the available online databases, and personal observations, to edit a high-resolution geographic grid-based map of the species occurrences and ranges, useful to match the palaeobotanical georeferenced data of *Arbutus* from late Quaternary fossil records. Range maps of past distribution have been produced for the last 30 ka at 1000-year intervals, based on pollen and macro-remains, including a total of over 1300 fossil sites. Pollen grains of the genus *Arbutus* are clearly distinct from other Ericaceae, although not identifiable at the species level.

In the Iberian Peninsula, the geographic range of *Arbutus* shows a surprising abundance even during the Last Glacial Maximum. An increasing density of occurrences during the postglacial period suggests a pervasive local persistence with an increase in population density rather than expansion. In the Italian peninsula, *Arbutus* is only detected starting from the Early Holocene. In the Eastern Mediterranean region, it is recorded since the Middle Holocene. It appears that a longitudinal pattern occurs in the population dynamics of *Arbutus* across the Mediterranean Basin in the last 30 ka BP. The local persistence of *Arbutus* along the Atlantic coast of France is difficult to assess, as even its recent scattered populations are not detected by pollen analysis. These marginal populations, as well as the sparse stands living along the coasts of the Black Sea, should be considered for conservation actions.

Ecoclimatic sensitivity in the tropics to Last Glacial Termination: climate change through data mobilization in the Neotoma Paleoecology Database

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Given the prospect of widespread ecosystem transformations caused by current anthropogenic climate change, a key research priority is to better assess the sensitivity of ecosystems to past, present, and future climate change. Better quantification of the ecoclimate sensitivity in the tropics is particularly critical, because of their high biodiversity, high carbon storage in rainforests, and positive feedbacks in carbon and water cycling. Global networks of fossil pollen records retrieved from lakes and mires are the primary data source for understanding climate-driven vegetation dynamics at local, regional, and global scales. Pollen data of the Neotoma Paleoecology Database, a community-curated paleoecology resource, historically were weighted towards temperate and high-latitude ecosystems in North America and Europe. However, recent data mobilization campaigns across the tropics now enable macro-scale analysis of tropical ecosystem ecoclimate sensitivity to climate changes since the Last Glacial Maximum (LGM).
Using Neotoma API services, we downloaded all pollen records from 23 thousand years BP (ka) to present between 25˚N and 25˚S. We selected data and temporal quality criteria, harmonized taxa lists using the new RFossilpol package (Mottl, Flantua et al., in review) and recalibrated all age-depth models using the *bchron* R package. We obtained reconstructions of global surface air temperature (SAT) data at 1.9°×2.5° resolution from Tierney et al (2020) and bilinearly interpolated all SAT temperatures to site locations. We estimated ecoclimate sensitivity by calculating community turnover from the LGM to present, then regressed turnover against LGM-to-present temperature anomalies. We analyzed the spatiotemporal patterns in ecoclimate sensitivity through mixed effects models with elevation and temperature predictor variables. The initial data retrieval from Neotoma yielded over 300 tropical records. We recalibrated age-depth models for 270 records and identified 73 records with at least one sample in the periods 5-2ka and 23-15ka. Initial results suggest a high community sensitivity of tropical ecosystems, particularly in montane regions. Variations among tropical regions in apparent climate sensitivity can be attributed to site factors such as elevational position and continentality. These results suggest that 21st-century climate scenarios will have substantial effects upon tropical plant distributions and community composition.

Benthic foraminifera and environmental changes in northern Sardinia: the case of the La Maddalena Harbour

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Benthic foraminifera are reliable tools to paleo-environmental reconstructions because they are wide spatial-temporal spread, and they are sensitive to short-time environmental changes induced by both natural and anthropogenic events. Their community structure provides useful information on the general characteristics of the environment quality and some species are sensitive to specific environmental parameters. Changes in benthic foraminifera abundance, species composition and variation in test morphology provide evidence of fluctuation in several environmental factors and can therefore be used as an efficient method for determining the ecosystems conditions.
This study presents the first micropaleontological data obtained through the analysis of a sediment core drilled from the shallow seabed (maximum depth 15 m) in the Ex-military arsenal of the La Maddalena harbour located on the southern-eastern coast of La Maddalena island (Sardinia, Italy). This area underwent different scenarios and environmental stresses over its history, in particular the investigated harbour worked as naval arsenal for nearly one century with heavy impact on the coastal zone. This study has been carried out to have information on the main environmental changes and to propose the most likely factors that caused these changes. The results showed that in the examined core, benthic foraminiferal assemblages were composed by over 90 species. The most frequent species were *Elphidium crispum, Ammonia tepida, Planorbulina mediterranensis, Spiroloculina ornata,* and *Quinqueloculina* spp.. Several biotic indices (species diversity, foraminiferal density, Shannon, Dominance, etc.) were also calculated. In general, the diversity indices show a decreasing from the first 50 cm of the core to the bottom. This slight decline is accompanied by changes in the foraminiferal assemblages. The results concerning changes in foraminiferal species composition, their abundance and biodiversity, supported by statistical analyses (cluster analysis), allowed identification of three major foraminiferal associations corresponding to different coastal-marine environmental settings.

Rescuing the red dog: using the Pleistocene fossil record of the dhole (Cuon alpinus, Pallas 1811) to inform modern conservation initiatives

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The dhole (*Cuon alpinus, Pallas 1811*) is a medium-sized evolutionarily distinct canid, currently distributed only in Southeast Asia after experiencing drastic range contraction and eventual extirpation from North America and Europe after the Late Pleistocene. Despite being threatened by prey depletion, habitat destruction and competition, little is known about the dhole's distribution and ecology. Dhole-specific conservation strategies are minimal, if not entirely absent in most range countries. Populations reside mainly in areas designated as protected for other charismatic species, such as tigers and elephants, but their adequacy for dhole conservation is undetermined. Species distribution models (SDMs) that relate georeferenced occurrence records to environmental variables could be used to identify suitable dhole conservation strategies. However, modern dhole distribution data is sparse and heavily influenced by human interactions, which could introduce bias into model projections and misinform conservation actions. Incorporating the dhole's Pleistocene fossil record into models could potentially reduce the effects of limited contemporary ecological data, by including palaeoclimate, palaeoenvironmental and competitive forcing factors over a longer time period. Fossil records can offer deep time insights into the responses to past environmental change of both individual species and ecological communities, as well as broadening understanding of species' full environment relationships prior to extensive human activity.

Population resilience of a wetland species near the limits of its range (the root vole Alexandromys oeconomus in Poland) vs. the geological history and connectivity of hydrogenic habitats – implications for species conservation

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Small, environmentally specialized species with a short migratory capacity are very sensitive to the loss of connectivity between habitat patches. This makes them very good for testing environmental changes. Habitat fragmentation, leading to the isolation of populations and consequently to gene pool depletion, may result from anthropogenic factors and/or natural processes of landform evolution. Differences can therefore be expected in how such habitats evolve in areas with different geological history, which in turn may give rise to different species responses to habitat change across such areas. The aim of the study was to examine how the geological history of the landscape close to the southern range limit of the root vole *Alexandromys* (*Microtus*) *oeconomus* in Poland affects the species' genetic variation and thus population resilience. The study was carried out at 9 locations, situated in two areas of Poland with differing geological surface structure characteristics: the Sandomierz Basin and western Polesie. The research included DNA analysis of root voles and geomorphological investigations. The analysis of DMT, satellite images, geological maps and cartographic field work showed that the habitats optimal for the root vole are configured differently in the two areas considered, occurring mainly in river valleys and in isolated wetlands of lake-land plains, respectively. Based on an analyses of 12 microsatellite loci (N=118) and the 908 bp of cytochrome b sequences (N=107), higher genetic variability was found in individuals from Polesie than from the Sandomierz Basin. Within the Sandomierz Basin itself, differences between results for populations from the Tanew and San valleys within the same catchment were further demonstrated. Simultaneous analysis of both the spatial configuration and connectivity of habitats, and the voles' evolutionary directions and genetic parameters, supports the conclusion that the linear character of highly fragmented riverine habitats, additionally inundated during episodic flooding, is less favorable for the gene dispersal of small mammals than extensive wetlands, even despite locally occurring barriers. We conclude that the geological history of the landscape needs to be taken into account in conservation management of hydrogenic habitat areas, especially those close to the range limit of a species with demanding habitat requirements.

Conservation efforts and paleobiology meet in the Coralligenous algal reefs

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The algal reef Coralligenous is one of the most important biogenic frameworks of the present-day Mediterranean continental shelf. As observed in its Quaternary records, it mainly consists of calcareous red algae and, to a lesser extent, of skeletonized invertebrates, such as bryozoans and serpulids. This complex and very heterogeneous habitat hosts a rich and diverse macro- and microfauna composed of several invertebrate taxa, among which mollusks, sponges and foraminifera are the most common elements.

The Italian FISR project "*CRESCIBLUREEF - Grown in the blue: new technologies for knowledge and conservation of Mediterranean reefs*" was aimed at the multidisciplinary exploration of the components, growth rate and accretion style of the Marzamemi (SE Sicily) coralligenous bioconstructions, and at the development of non-invasive techniques for the study and conservation of this priority habitat. The data collected range from remote sensing maps to the monitoring of environmental parameters, to the analysis of the components identity, their association, and radiocarbon age, that enable a reconstruction of the temporal and spatial dynamic of Coralligenous, and its role as archive of environmental changes trough the Holocene. This wide data set, including both the physical habitat engineers (calcareous algae, bryozoans, serpulids, mollusks) and the macro- and micro-dwellers, suggests that Coralligenous is a geo-historical structure and major in situ recorder of the coastal dynamics trough time and space, providing new hints about the response of the Mediterranean shelf environment to the Holocene climatic fluctuations and historical human impacts.

The formation and time averaging of shell beds of Lake Tanganyika, Africa: Implications for conservation of a unique lacustrine habitat

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Lake Tanganyika, Africa, hosts an extraordinary level of faunal diversity, much of which occupies the nearshore (littoral) environments of the lake. Threats to the lake's biodiversity stem from both lakewide impacts (e.g. climate change), but also local impacts (e.g. sediment pollution and overfishing) that also vary spatially and temporally. Up to 30% of the lake's littoral area consists of shell beds, in water depths of 5-40 m, dominated by a single gastropod species (*Neothauma tanganyicense*); these shell beds form habitats for cichlids, ostracodes, sponges and other mollusks. Our observations over the past decade are that these shell-bed substrates are variably impacted by surface sedimentation, creating patchy or completely buried shell beds in some areas. Further, living *Neothauma* are rare to absent within these shelly substrates at some locations, implying either a negative feedback, where accumulation of dead shells limits the presence of modern populations, or the presence of acute anthropogenic impacts that are reducing populations of the snail at least locally. Radiocarbon dating of surficial shells, corrected for a carbon reservoir effect in the lake, suggest shell production varied with changes in climate and lake level. Shells as old as 3100 yrs before present (BP) exist, but production peaked between 1600-1200 yrs BP, when the lake was lower and climate more arid. A second mode of shell ages corresponds to the Little Ice Age, when lake level again was slightly lower. There is an age gap in shell production between these time periods, which is marked by a lake transgression (wetter climate). In regions of the lake where nearby land disturbance is high, the shell age distributions reflect limited shell production in the last 100 years, suggesting that anthropogenic sediment input may be inhibiting shell production. This is also consistent with changes in ostracod diversity and sponge abundance data. A breakdown of the shell-bed habitat will likely have a cascading effect on other organisms and is a threat to overall biodiversity of the lake. Conservation methods, however, will need to differ relative to those employed along rocky shorelines of the lake because of differences in population pressure and land use.

Changes in small mammal community composition over the last 25,000 years across multiple western North American cave localities

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Natural Trap Cave (NTC) is an 80-foot deep karst sinkhole located at the base of the Bighorn Mountain range in Wyoming, USA. An exceptional fossil record of microfaunal remains are found from well-stratified layers in the cave stretching back 30,000 years ago, before the end-Pleistocene megafauna extinction, up until a few hundred years ago. While many studies have examined how communities respond to environmental changes in a single location through time, few have observed how community responses vary across different habitats. We compared standardized richness, evenness, and relative abundances, using NISP, of the small mammal communities from NTC, Samwell Cave, Two Ledges Chamber, and Homestead Cave to observe how small mammal communities shifted through time across diverse landscapes. Then, a closer look was taken at the shifts in functional traits of the small mammal community of NTC. Results from a PCoA found that NTC and Samwell Cave were more similar to each other than to Homestead Cave and Two Ledges Chamber. Despite differences in local environments, open and arid at NTC and closed and forested at Samwell Cave, small mammal accumulation at both these caves are the result of packrat midden collection. Richness and evenness were then compared between NTC and Samwell Cave. We found that evenness decreased at both caves from the Late Pleistocene to the Late Holocene. Richness also decreased through time at Samwell Cave but increased through time at NTC, though this may be influenced by small sample sizes in the Late Pleistocene. The Pleistocene community at NTC had the highest percentage of taxa with low tooth crown heights (42%) with that percentage reducing by half into the Holocene. Dietary generalists were also more common in the Pleistocene community (61%) with communities dominated by taxa eating exclusively plants in the Middle Holocene (62%) and Late Holocene (57%). It may be that as temperatures warmed into the Holocene, plants around NTC diversified allowing more herbivorous taxa to increase in abundance whereas those focusing on invertebrates, fruits, or seeds were more limited.

The late occurrence of hunter-gatherer occupation of tropical rainforest in northwestern Thailand

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Archaeological sites in highland Pang Mapha, Mae Hong Son Province in northwestern Thailand have yielded several Late Pleistocene to Holocene human and animal remains associated with the Hoabinhian techno-complex. Savannah-like grasslands have been suggested to be a hunter-gatherer related habitat during the late Pleistocene based on the stable isotopic evidence, while other archaeological data have implied rainforest specialization for Holocene hunter-gatherers. However, human reliance on rainforest resources in the region has not been demonstrated comprehensively. To refine the timing of dietary changes and ecological adaptations of hunter-gatherers, we measured stable carbon isotope compositions of tooth enamel of humans and their associated mammals from several archaeological sites in highland Pang Mapha, dated between 9,800 and 1,100 yr BP, and compared the isotopic results with previously analyzed data from the late Pleistocene archaeological site of Tham Lod Rockshelter. The stable carbon isotope data have revealed that the significant dietary shift of hunter-gatherers to more exclusive C_3 food items occurred around the early Holocene or probably during the Pleistocene-Holocene transition, and their succeeding reliance on rainforest resources possibly remained consistent in the region throughout the Holocene. Subsistence strategies with more emphasized rainforest foraging illustrate an ecological adaptation of Hoabinhian populations in response to more homogeneous and closed environments and wetter climate in northwest Thailand after the end of the Pleistocene. Compared to other neighboring regions, our isotopic results document the late occurrence of mainland Southeast Asian rainforest hunter-gatherers.

Microblade Runner: Changing environments and the emergence of microblades in the northern Japanese archipelago

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The appearance of microliths and their rapid spread throughout Eurasia is one of the major developments in the evolution of Paleolithic technologies, since microliths and microblades, as part of complex modular tool packages, became the dominant technology in the late Pleistocene and persisted into the Holocene. The pressure flaking techniques associated with microblade technologies in East Asia are argued to have emerged in northern Asia, with some discussion of northern Japan as a possible region of initial emergence. As such, much research has been done on the function, variability, and timing of microblade industries in the region. Qualitative assessments of the archaeological record and the Paleoenvironmetal reconstructions suggest the emergence of some microblade industries as a response to the changing environments. These arguments can be strengthened through additional quantitative analyses. This project constructs a diffusion model of microblades in northern Japan and conducts a spatial analysis between the emergence of microblades and the Paleoenvironments in order to explore how hunter-gatherers in northern Japan adapted their technological toolkits to the rapidly changing environments of the late Pleistocene.

Rethinking the diversity of lithic technology and human behaviour in the terminal Pleistocene of Hokkaido, Northern Japan: a view from bifacial point traditions

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In understanding the behaviours and adaptive strategies of the terminal Pleistocene (19-11.5 cal ka) human populations in Hokkaido, Northern Japan, much attention has long been focused on the evolution of microblade technology. There is a large body of research on the issue of human behaviours in lithic assemblages where microblade technology is recognised. However, recent findings from several archaeological sites in Hokkaido have confirmed the development of bifacial point traditions during the terminal Pleistocene. Understanding of the behaviours and adaptations of these bifacial point producing populations in Hokkaido is an important question in discussing the dynamics of human populations from Northeast Asia to North America during the terminal Pleistocene. How to interpret the relationship between people who produced microblades and those who produced bifacial points is also an issue that researchers need to address. In addressing these issues, the uncertain dating of lithic assemblages with bifacial points in Hokkaido has so far been a major barrier to progress the debate. In this paper, I explore the bifacial point traditions of the terminal Pleistocene Hokkaido in terms of its chronology, distribution, and lithic technology. In addition, I discuss how the occurrence and development of bifacial point traditions in Hokkaido can be assessed in the light of the characteristics of bifacial point lithic assemblages in the Japanese archipelago.

Using calibrated surface roughness dating to estimate coastal dune ages at K’gari (Fraser Island) and the Cooloola Sand Mass, Australia

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Here we present a novel application of landscape smoothing with time to generate a detailed chronology of a large and complex dune field. K’gari (Fraser Island) and the Cooloola Sand Mass (CSM) dune fields host thousands of emplaced (relict) and active onlapping parabolic dunes that span 800,000 years in age. While the dune fields have a dating framework, their sheer size (~1930 km^2) makes high resolution dating of the entire system infeasible. Leveraging newly acquired (n=8) and previously published (n=20) optically stimulated luminescence (OSL) ages from K’gari and the CSM, we estimate the age of Holocene dunes by building a surface roughness-age relationship model. In this study, we define surface roughness as the standard deviation of topographic curvature for a dune area and we demonstrate an exponential relationship (r^2 = 0.942, RMSE = 0.892 ka) between surface roughness and timing of dune emplacement on the CSM. This relationship is validated using ages from K’gari. We calculate surface roughness utilizing a 5 m digital elevation model (DEM) and apply our model to predict the ages of 726 individually delineated Holocene dunes. The timing of dune emplacement events are assessed by plotting cumulative probability density functions (PDFs) derived from both measured and predicted dune ages. We demonstrate that both dune fields had four major phases of dune emplacement peaking at <0.5, ~1.5, ~4, and ~8.5 ka. We observe that our predicted dune ages did not create or remove major events when compared to the OSL-dated sequence, but instead reinforced these patterns. Our study highlights that surface roughness-age modelling can be an easily applied relative or absolute dating tool to dune fields globally. This systematic approach can fill in chronological gaps using only high-resolution elevation data (3-20 m resolution) and a limited set of dune ages.

Points to keep in mind when predicting the impact of sea-level rise on coastal ecosystems: Focusing on mangrove ecosystems

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Early studies to predict the effects of sea-level rise induced by global warming on mangrove ecosystems were often conducted using geomorphological and geological methods, which were estimated the threshold rate of past sea-level rise that mangrove forest floor deposits, especially mangrove peat, could catch up from their spatial distribution and sedimentary age. These studies clarified that mangrove forests, which had maintained their habitat by accumulating mangrove peat with a small amount of sediment inflow, were submerged under sea-level rise exceeding 5 mm/year. However, our subsequent studies on Pohnpei Island in Micronesia, where a sea-level rise exceeding 8 mm/year has been observed in recent years, clarified that the ground level in the communities of *Rhizophora* spp. has been rising due to the deposition of mangrove peat, though the *Sonneratia alba* community located at the seaward forest edge and the *Bruguiera gymnorrhiza* community where the tree density of *Rhizophora* trees has been decreased due to vegetation succession have already been undergoing significant surface erosion. Namely, the mangrove peat sedimentation rate estimated by the geomorphological and geological methods was the average value in the order of hundreds to thousands of years, and the decline in mangrove peat accumulation rate due to vegetation succession was not considered. In recent studies, the vulnerability of mangrove forests was often evaluated from changes in the distribution area of mangrove forests using satellite images, but phenomena such as surface erosion occurring in forests were not captured. In addition, mangrove forests were treated collectively in many cases, and evaluations were not made at the community level. Ground elevation changes in mangrove habitats are controlled by root system dynamics including dead roots, especially fine roots which are the main parent material of mangrove peat, in addition to allochthonous sediment budget. Fine root productivity and dynamics differed depending on species and site environments. To predict the impact of sea-level rise more accurately, it is necessary to evaluate not only geomorphological processes such as sediment budget but also biological processes such as root system dynamics at the community level.

Computing of uncertainty subsidence-associated along a 2D geological model in the Po Delta Area (northern Italy)

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Quantifying uncertainty in geological problems is not an easy task, although it plays a fundamental role in ensuring robust and accurate results. In fact, uncertainty affects a wide range of fields, including the natural variability of a system, the sampling rate of key parameters used for describing a system, measurement errors, modeler's experience, etc. Some of the approaches that deal with uncertainty treat the error sources in a single and non-integrated manner, while more advanced procedures consider the impact of uncertainty based on geostatistical methods, or by combining geostatistics and stochastic simulations arising from multiple sources of error. In the present study, we propose a workflow to account for the "multiple-source uncertainty" associated with a 2D geological model aimed at assessing natural subsidence rates in deltas. The geological section that we modeled crosses the Po Delta (northern Italy) and involves the late Pleistocene-Holocene sequences. We first focused on the factors that control uncertainty in the geological modeling finalized to subsidence computation (e.g., instrumental error in the horizon picking or different depth interpretation for the same horizon). Then, we isolated the effect of the single source of error on each calculation step of the backstripping procedure, which has been used for the quantitative subsidence assessment (e.g., sediment compaction or isostatic loading steps). Afterward, we evaluated the effects of concatenated errors on the final result, performed a sensitivity analysis and identified the source with the highest influence on the uncertainty. In addition, we focused on the empirical relationships among the analyzed uncertainty factors.

Finally, we compared uncertainty estimates related to subsidence computation from different commercial softwares and research scripts available in the literature, and automated the best procedure in a Matlab code.

The geomorphology and significance of perched coastal lakes in Ireland

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Perched coastal lakes, located within the elevation range between present sea level and the position of the mid-Holocene maximum recorded along any one coast, have the potential to record late Holocene coastal sediment dynamics, especially along coastlines that have subdued glacioisostatic influence but where they may be exposed to storms or other drivers of large waves (such as tsunamis). Although many individual coastal lakes globally have been examined with respect to their overwash chronologies, there have been few studies that have (1) considered the typologies of different coastal lakes in a single region, (2) compared the geomorphology and sedimentology of these lakes in order to better understand their different evolutionary patterns and controls, and (3) compared the overwash records of adjacent lakes to understand the spatial and temporal patterns of storm events across a region, rather than from just a single lake whose record may be incomplete or unrepresentative. This study takes the first step towards resolving these three issues by considering the different perched coastal lakes that are present around the coasts of Ireland. This study maps and then classifies these lakes (approximately 50) in terms of their elevation, size, substrate type and seaward bar. Broadly, four lake types are identified according to their seaward bar (bedrock lip, gravel ridge, sand dune, beach/barrier). These are located along different coastline types (bedrock controlled, sediment dominated) and with respect to the trajectory of local relative sea-level change (by glacioisostatic-driven emergence/submergence). These types are characterized by different patterns of geomorphic development, related to coastline sediment supply, the likelihood of wave washover, and landward sediment transport. This has implications for sediment infilling of the lake basin, infill stratigraphy, and the likelihood of storm overwash sediment signatures being preserved. (Palaeoecological and water salinity proxies of overwashing are not considered in this study.) A subsample of test sites and their results of geomorphic and sedimentary mapping are presented in this study, and this provides a baseline for a systematic survey of coastal lakes across the Irish coast.

The tectonic rock uplift history of northern Guam (Mariana Islands) deduced from marine terraces

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Guam is the southernmost island of the Izu-Bonin-Mariana island arc system associated with the subduction of the Pacific under the Philippine Plate. The island is part of a unique tectonic setting that led to the formation of the deepest subduction trench and the only modern active submarine serpentine volcanoes on Earth. It is a seismically very active zone with more than thirty earthquakes of magnitude higher than three per year and coseismic events that can cause vertical displacements of ca. 10 cm.

The northern part of the island is capped with uplifted limestone with a series of marine terraces that allow studying of long-term tectonic uplift history. Our research focuses on the highest set of terraces. Geomorphic mapping and morphometric analysis based on high-resolution DEM were used for terrace identification and modelling of the uplift rate. For age model control points, U-Th dates obtained from datable corals found on the lowest terrace, and speleothems from flank margin caves were used.

Our preliminary results indicate that the northern part of the island episodically uplifted (at least three times); however, it was also strongly denudated during the Pleistocene, which was taken into account when quantifying the rock uplift rate. The results also show the complexity of the tectonic history of the island and its surroundings. They will not only help to understand the formation of some of the unique features of the planet, but also help to better comprehend Guam's aquifer that developed in such conditions, which provides fresh water to the growing population of the already densely populated island.

Geomorphological map of the Tyrrhenian coastal sector of the northern Calabria-Basilicata (southern Italy)

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In this work, we present the 1:20,000 scale geomorphological map of the Basilicata-northern Calabria coastal stretch of the Tyrrhenian coastal sector of the southern Apennines (Italy). The study area spans for c. 20 km from Maratea in the North to Scalea in the South, and is particularly interesting for the presence of a well-preserved staircase sequence of marine terraces located from a few m up to ~ 170 m a.s.l. They consist of both erosional and depositional paleo-shorelines in several instances covered by alluvial fans. In addition, evidence of cross-cut relationships between the paleoshorelines, deposits (e.g., slope/alluvial fan deposits and speleothems) and landforms (karst caves and conduits) of terrestrial environment occurs.

The geomorphological map synthesizes the results of a detail-scale study carried out in the last years that was based on the combination of field surveys with the geomorphological analysis of detailed topographic data (1:5,000 scale topographic map, LiDAR data with 1 and 2 m resolution and a 5 m resolution DEM) and integrated by geochronological dating of several marine and continental environment deposits. The new chronological data provide constraints to the formation of the marine terraces in the elevation range of 2 - 60 m a.s.l. and, therefore, allow us to extend the sequential reconstruction to the marine terraces located above 60 m a.s.l. In addition, marine terrace dating allows us to reconstruct the main stages of both coastal and continental landform sculpturing and, therefore, constrain and distinguish several stages of alluvial fan growth and progradation.

All such information has been reported in the geomorphological map. In fact, besides careful and detailed mapping of the coastal and alluvial/slope landforms that occur in the study coastal stretch, information in the map synthesizes the stages of the geomorphological evolution of the study area during a time frame that spans from the Middle Pleistocene to the latest peaks of the Last Interglacial (LIG).

Holocene coastal response to sea level rise of high coasts in quite stable areas: the case of Punta Licosa promontory(Campania Region)

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Punta Licosa promontory is located in the northern part of Cilento coast in the southern Tyrrhenian basin. This promontory is bordered by cliffed coast connected to a wide shore platform sloping slightly towards the sea. This area is considered stable at least since Late Pleistocene, as testified by a series of evidence, well-known in literature.

The aim of this research is to reconstruct the main coastal changes occurred in this area since the late Holocene by means of literature data, aerial photo interpretation, satellite images, GPS measurements, direct underwater surveys, GIS elaborations of high-resolution DTMs, bathymetric data and high-resolution orthophotos taken by UAV.

Particular attention was paid to the wide platform positioned between -6.0 ± 2.0m MSL and the present MSL, being these coastal landforms interpreted as the main consequence of seacliff retreat. The spatial analysis of this landform was compared with the GIA models calculated for the southern Tyrrhenian area, allowing establishing that it was shaped during the last 6.0 ± 2.2 ky BP. The interpretation of archaeological and geomorphological markers allowed defining the shoreline evolution of this coastal sector since 6.0 ky BP which can be well depicted by two morpho-evolutive scenarios.

The first scenario is related to 6.0 ± 2.2 ky BP, and it is relative to the time when the decreasing rate of sea-level rise favoured the seacliff retreat in the whole coastal sector and the starting point of the platform formation, testified by the outer margin of the present-day platform.

The second scenario is related to 1.0 ky BP, as testified by the remains of the roman harbour located at S. Marco di Castellabate, in the northern part of the study area, being harbour structures excellent sea-level indicators, as they were built in direct functional relation with the ancient sea level. The Related RSL at this time can be located at -1± 0.3 m MSL.

This research provides new data useful for climatic studies aimed at evaluating the high coast vulnerability to the effects of the ongoing accelerated RSL along the Cilento coast representing a perfect example of Holocene coastal evolution in quite stable areas.

New insights into the palaeolandscape of the Scheur, a hotspot for Late Pleistocene fossils off the Belgian coast

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Over the past decades, bottom trawling and dredging in the vicinity of the 'Scheur' navigation channel (~5 km NE of the harbour of Zeebrugge, Belgium) has yielded vast amounts of unique Late Pleistocene palaeontological material. Besides finds related to prehistoric land mammals (including mammoth, woolly rhinoceros, aurochs and straight-tusked elephant), an exceptional quantity of walrus (*Odobenus rosmarus*) bones has been discovered. The walrus assemblage contains remains of 50 to 100 animals (both males, females and juveniles), which are most likely preserved *in situ* because they show no or little signs of abrasion. It can therefore be concluded that at some point(s) in the Late Pleistocene, one or multiple walrus colonies must have lived in the Scheur area. However, several questions remain to be addressed: (i) From which stratigraphic level(s) are the walrus fossils sourced? (ii) What is their age (given that radiocarbon dating indicates an age beyond the detection limit, > 45000 yr BP)? (iii) Why do we find such a large abundance of fossils in this specific area, so unusually far south? Key to answering these questions is a better understanding of the geological context and evolution of the Late Pleistocene coastal/nearshore landscape off Zeebrugge. This study contributes to this need by presenting new geophysical (ultra-high-resolution sub-bottom and multibeam) data and information from sediment cores. The results have led to the identification of a potential source layer for the walrus fossils, shed new light on the diversity in and stratigraphic superposition of sedimentary environments in the study area, and reveal the influence of human activities (specifically, dredging of the navigation channel) on the denudation of the fossil-rich strata. With this new information, more targeted sediment sampling, geophysical data acquisition and visual seabed inspections can be planned, to further elucidate the relationship between the abundant presence of (walrus) fossils and the Late Pleistocene landscape evolution around the Scheur.

Geoarchaeological analysis to unravel the ancient settlement dynamics: examples from the Ionian coastal landscape of Basilicata, southern Italy

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In the ancient territory of the Greek settlements of Heracleia and Metapontum (Ionian sector of Basilicata, southern Italy) geomorphological mapping, GIS-supported statistics, and landform topographic features were investigated and combined to extract settlement rules and site dynamics. Analyses of environmental dynamics as well as of spatial and temporal settlement evolution were carried through an integrated approach that, starting from a detailed geomorphological analysis, tried to extract the spatial relationships between archaeological site locations and landform/landscape features. Spatial analysis was used to investigate the relationships between environmental parameters and archaeological sites (i.e., between humans and the evolving environment). The analysis was carried out in two distinct areas, each about 50 km-large, including the main settlements and other sites of that territory. A model describing interactions between sites and parameters such as elevation, slope, aspect, landforms, land use, and distances from rivers was constructed. In the present work, emphasis has been put to analyze the sensibility maps deriving from the selected parameters and their changes through time from Prehistorical and Protohistoric Ages to Roman period for five archaeological categories, i.e. Settlement, Productive area, Farmhouse, Necropolis and Sacred area, contextualized within the most likely paleoclimate scenario. Sensitivity maps are able to unravel the settlement dynamics in the study area, relating them to both social-political transformations and landscape evolution mainly linked to the sea-level changes.

Present-day bathymetry and paleocoastline modelling – perhaps not such a good idea? A case study from the Gulf of Trieste, northern Adriatic Sea

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Paleoreconstructions are becoming increasingly important as we try to understand and predict future changes of our environments. This also applies to paleo-landscape modelling of present-day coastal areas in an effort to better understand future challenges related to sea-level changes. One aspect of coastal paleoreconstruction deals with geographical modelling of paleocoastlines. Here, the two main factors controlling the results are the used sea-level curve and paleotopographical model. While significant efforts are usually dedicated to produce and/or use the most representative sea-level curve, more often than not, present-day bathymetry is used as the topographical model input. While this can be an acceptable approximation where not much variation is expected in the topography, it can potentially induce significant errors in settings where the present-day bathymetry considerably differs from the pre-transgressional topography. This study considers one such example - the Gulf of Trieste (northern Adriatic Sea), a low‐gradient area with fairly well-resolved bathymetry and pre‐Holocene (i.e. pre‐trangressional) paleotopography. Both topographical models are used for paleocoastline modelling in order to determine the variability of the modelled coastline locations. The results demonstrate that coastlines determined from the two different input topographies can differ by as much as a few kilometers resulting in significantly different landscape reconstructions. Present-day bathymetry in paleocoastline modeling should be used very cautiously and only in settings where not much topographical variability is expected since the sea-level rise/fall. The findings of this study are especially important for low-gradient continental shelf areas where even small sea-level variation can affect vast expanses of the shelf.

Unveiling the Brazilian equatorial margin: the Potiguar Basin shelf-edge.

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The study area is located between 100 m and 2000 m deep, along the coast of Rio Grande do Norte State, Northeast Brazil. It is in the transition between the continental shelf, site of future offshore wind installations, and deep waters, new oil exploratory frontier in the so-called Equatorial Margin. The main objective of the research was to generate knowledge to support the sustainable management of natural resources and energy in sensitive marine areas, associated with the training of human resources, as well as contributing to the Decade of the Oceans. The data were collected aboard the Hydro-oceanographic vessel Cruzeiro do Sul, in a partnership between Brazilian educational institutions, the Brazilian Navy and the Brazilian Geological Service. Data from multibeam bathymetry (MBES), high-resolution seismic (CHIRP), measurements of speed of sound along the water column (XBT) were acquired, among others. The results indicated the presence of different marine features and potential areas to Geohazards on the slope. In particular with emphasis on submarine canyons, which have the potential to lift and transport cold water masses (upwelling) over the shelf and edge of the continental shelf. These results confirm, in unprecedented detail, recent studies that showed that submarine canyons generate the ideal flow-topography environment, inducing the process of seasonal uplift (greater intensity in summer) of colder and saline water masses from the deepest to the shallowest areas, resulting in the formation of vortices, ecological differentiations, as well as the seasonal fertilization of the waters of the Northeast coast of Brazil, breaking the paradigm of an exclusively oligotrophic zone.

Using archaeological and geological data to reconstruct human-environment interaction on and around the former (pen)insula of Testerep (Belgium)

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The Middle Belgian coastal area has been subject to many changes over the past 5000 years. Currently dominated by a linear dike platform, the area previously consisted of a dynamic system of tidal gullies, mud flats, and marches. The emergence, reclamation, and eventual partial demise of the (pen)insula of Testerep in this area is a great example of sea level rise impact on coastal landscapes and communities. The Testerep project focusses on reconstructing the evolution of this former (pen)insula. This will include the integration of new and existing on- and offshore data in a GIS-database. This GIS-database, which will include data obtained through a.o. LiDAR, geophysical surveys, coring and excavations, will be a basis for reconstructions and modelling of the physical landscape.

The setting up of this database also allows for insights into human-environment interaction on a local scale. Over 200 archaeological observations were made in the Testerep-area. In some cases, studying the evolution of specific sites allows us to learn about the way specific coastal communities adapted, or failed to adapt, to their coastal environment. Roman and Medieval settlements developed in the coastal plain, taking advantage of the opportunities provided by proximity to the sea. Despite a strong and maintained Roman presence on a nearby sandy outcrop overlooking the coastal plain, and apparent investments in localised coastal defence, Roman sites nearer the coastline appear to have been overtaken by the sea in relatively short timespans. Early and High medieval habitation in the coastal plain appears to be limited to areas further away from the coastline, on natural outcrops and elevations. High and Late Medieval coastal communities settle in the coastal plain, taking advantage of natural defensive opportunities and creating them when not available. The apparent longer lasting success of these settlements is due in part to historically attested investments in coastal defense. Many excavation reports include underutilised geological information. Integrating this information with larger geological datasets can add to reconstructions of the physical landscape. Studying the impact of settlements on the environment and vice versa can provide useful factors to include in later modelling phases of the project.

Estuarine coastline evolution of the northern Tagus margin combining geological, archaeological and cartographic data

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In this work we present the results of a cross-disciplinary study aimed to reconstruct the evolution of the northern Tagus estuarine coastline in the Lisbon old city centre. Based on sedimentological analyses, archaeological findings, and old cartography, we propose different and consecutive steps for the anthropic *conquer* of the estuarine margin since the Iron age/Roman period.

The first occupation of the marginal area took place during the Iron age, with the construction of several housing buildings on the berm of beaches forming the downstream margins of a Tagus estuary tributary (Esteiro da Baixa; EB). In the Roman period, the EB and the proximal Tagus margin were densely occupied by several public housing, production structures, and harbour facilities, certainly constraining the EB margins. Based on archaeological findings and its typology, urban morphology, altimetry and sedimentological analyses performed in sediments collected in marginal archaeological sites, an estuarine coastline was proposed for the Roman period. According to these data, the coastline located ca. 400 m inland from the present-day coastline.

During the Medieval period the margin continued progressively to be conquered essentially by the deposition of waste deposits, that later are occupied and used mostly for the development of anthropic maritime-related activities. During the Late Medieval ages, the successive advances of the estuarine coastline are materialized by the construction of the defensive city walls during the reigns of D. Diniz and D. Fernando respectively that, in the Lisbon downtown, mark the land-estuary limit. Later, during the 15th/16th centuries, D. Manuel I promotes a reorganization of the area, renewing the importance of Lisbon downtown by the construction of a new and important landfill that moved southwards the estuarine coastline by ca. 200 m.

The 1755 seismic/tsunami event severally damaged Lisbon and the estuarine frontline, and during the following years an effort was done to rebuild the city. Finally, during the 19th century a vast new landfill was constructed, the Aterro da Boavista, linearizing and artificializing the margin in an extension that covers the entire municipality.

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Stratigraphic architecture of the Rhone delta in the Holocene: Relationship between sedimentary flows in the delta and Climatic & Anthropogenic impact in the Rhone basin

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Deltas are vulnerable ecosystems, sensitive to variations in sedimentary input and sea level. Projections indicate that by 2035, 75% of the population will live within 100 km of the coast. The study of the morphological response of deltas to climate change is therefore essential.
The Rhone delta is located at the outlet of a watershed of 97 800km2 and currently covers 1740Km2. It began its construction about 7000 years ago thanks to a slowing down of the rise of the sea level and to strong sedimentary contributions. The successive functioning of several sedimentary lobes: Saint-Ferréol, Ulmet, Peccaïs, Bras de Fer, Roustan, ... allowed the delta to prograde on the sea.
The sedimentary data in the delta have been made available through the collaboration of several academic teams (IFP Energies Nouvelles, EVS-University Lyon 2, IFREMER, University of Bologna, Cerege). This study proposes an update of the stratigraphic architecture of the Rhone delta during the Holocene through the analysis of about fifteen cores located in the emerged delta and the Rhone prodelta.
The identification of depositional environments and the contribution of new dates have allowed the realization of correlation transects on the Rhone delta as well as the updating of paleo-maps of the delta. The calculation of sediment flux and the analysis of the chemical composition of the cores have allowed the identification of sediment sources and flux variations during the Holocene.
All these data are related to previous work in the Rhone basin. The aim is to identify the climatic and anthropic contributions of the watershed on the Rhone delta from the millennial to the centennial scales.
The contribution of these new data constraining the stratigraphy of the Rhone delta during the Holocene and the link with the functioning of the watershed make possible the modeling of the Rhone delta building. This stratigraphic modeling allows to test the coupling between the physical processes of the watershed and the resulting geological objects in the delta. This modeling (with Dionisos software) covers the entire Holocene until the anthropocene forcing period, and will allow the realization of several predictive scenarios for the year 2100.

Morfo-evolutive study of Gaeta Bay (central-southern Tyrrhenian sector) during the Late Holocene from geoarchaeological and geomorphological data

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This research aims to present the first geoarchaeological data from a multidisciplinary study carried out along the coasts of the Gulf of Gaeta in order to identify possible evidence of recent tectonic activity. The study area has never been extensively studied from a late Quaternary geological/geomorphological evolution point of view and its morphology is the result of the interaction between significant structural features and the action of slope and littoral morphogenetic processes.

Since the end of the 2nd century BC, the Gulf of Gaeta experienced a large urban development associated with the construction of numerous maritime villas and quays. In this key, this research presents results related to several geoarchaeological direct and indirect surveys performed along the coastal sector between Formia and Gaeta municipalities.

The direct investigations concerned numerous ancient Roman structures characterized by the presence of structural elements (i.e., fish tanks, pilae, and breakwaters), directly related to the former sea level and considered among the most accurate sea-level markers, together with extensive geological and geomorphological surveys. Where possible, direct underwater measurements were coupled with extensive indirect morpho-acoustic and optical analysis.

The GIS-aided analysis of the collected data combined with a high-resolution digital terrain model (DTM) from Lidar and iconographic research allowed for the reconstruction of the high-resolution geomorphological map showing the precise position of archaeological structures identified and to propose its detailed interpretation of the Late Holocene evolution of this coastal sector.

In particular, our results suggest that the local sea level during the Roman period (I century BC) was no higher than - 0.55 ± 0.29 m MSL. These results largely agree with the GIA models (ice sheet chronologies ICE-5 G, ICE-6 G and the coupled ice sheet-sea level ANICE-SELEN model) specifically calculated and published for this coastal sector, highlighting the tectonic stability of this sector during the last 2.0 ka.

Characterization of alongshore variation in coastal erosion by a wave energy model

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Determining the rates and modes of rocky coast erosion remains a fundamental challenge for coastal scientists and engineers. The analysis of rocky coastal evolution is difficult due to the imperceptible change at the human scale, the complex relationship and feedback between a wide range of formed processes, and the lack of field data and a deep understanding of some processes, such as nearshore hydrodynamics. Numerical models have long been used to better understand coastal evolution and to calculate rates and modes of erosion at different time and spatial scales, especially on hard-rock coasts. However, models usually simplify estimates of coastal erosion by ignoring nearshore hydrodynamics such as wave energy dissipation during breaking. We aim to understand how the distribution of the breaking point locations, given a certain bathymetry with local variations, affects the wave energy transfer from deep water to the shoreline and so the spatial variability of rates of coastal erosion. We developed a numerical model that allows us to calculate: (1) the location of the breaking point and the surf zone width, and (2) the surf energy of those waves reaching the shoreline. Then, we characterize the alongshore variation of coastal erosion rates. We find that the distribution of breaking point locations is heavily influenced by nearshore bathymetry and deep-water wave regime (height and period). Given certain bathymetry, the possibility of breaking near the shoreline and producing erosion is achieved only by small waves (H_0 = 1 m) with short periods (T = 6 s).

In those places where waves break near the shoreline, they have enough mechanical energy to erode the coastal rocks. In addition, the possibility that waves break closer to the shoreline is increased by local bathymetric variations that become the seabed steeper. In those places where the breaking point is almost at the shoreline, we observed maximum erosion rates. Thus, by knowing the wave regime, bathymetry, and some rock parameters such as lithology, we may expect certain ranges of coastal erosion rates according to this wave energy transformation model.

Late-Holocene relative sea-level changes and palaeoenvironment of the Pre-Viking Age ship burials in Saaremaa Island, eastern Baltic Sea

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Two unique Pre-Viking Age ship burials were found from Salme village, Saaremaa Island, Estonia, containing remains of seven men in the smaller and 34 men in the larger ship. According to the archaeological interpretations, these ships belonged to a viking crew who possibly came from the Stockholm-Mälaren region, eastern Sweden.

Geoarchaeological research was conducted in the area to reconstruct Late-Holocene relative sea-level (RSL) changes and to provide environmental context to these burials. A new Late-Holocene shore displacement curve shows an almost linear RSL fall from 5.5 to 0.8 m a.s.l. between 1000 BC and 1300 AD with an average rate of 2 mm/year. A slowdown in regression may be attributed to accelerated sea-level rise after the Little Ice Age and during the industrial period, being consistent with the tide-gauge measurements from the 20th century.

Salme ships were buried sometime between 650–770 AD into the sandy-gravelly coastal deposits which had accumulated in the open coastal zone about 710–450 years earlier. GIS-based palaeogeographic reconstructions indicate the existence of a narrow strait in the Salme area at this period. The wind-protected shores of the strait were probably the most suitable places in the area for landing the viking ships. A sedimentological study with palaeoreconstructions show that the ships were not buried on the beach but were located about 2–2.5 m above coeval sea level and more than 100 m from the coastline. The orientation of the ships suggests that they were probably moved from the shore of the Salme strait to the higher ground for burial. The sedimentological evidence and diatom data show the narrowing of Salme palaeostrait between 1270 and 1300 AD, resulting in the strait becoming a river.

Understanding the activity of rocky coastal cliffs: an exploration from numerical models

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Cliff activity in shoreline systems is modulated by several processes, such as landmass uplift, marine erosion, previous topographical conditions, and changes in global sea level. We present here an exploratory numerical model to study the influence of these processes on the activity of coastal original cliffs. These original cliffs are formed at the beginning of the modelling; that is, the upper, older cliffs in model profiles. This model purposely considers values of uplift (rates and onset), marine erosion factor, and initial topography according to the Great Coastal Cliff in the Atacama Desert in Northern Chile. This cliff is the tallest and most uninterrupted coastal cliff on Earth. The results of the model show that a faster uplift rate (> 0.3 mm/yr) or an older onset of uplift (3 Myrs) favors the formation of inactive cliffs, whereas active cliffs form under conditions of a slow uplift rate (0.2 mm/yr) or a younger uplift onset (1 Myr). Given certain rate and onset of uplift with no considerable spatial variations, low erosion (< 1 m^2/yr), allows the preservation of sequences of staircase marine terraces, leaving behind an inactive coastal cliff. On the contrary, high erosion (>1 m^2/yr) totally erases any marine terrace in formation, keeping the cliff activity. The effect of erosion on the cliff activity is enhanced or reduced by the initial topographic slopes. Steep coasts (> 5-10°) may hamper cliffs to reach an inactive state. Thus, our model is capable enough to gives information about the relative importance of these variables on the development of active and inactive cliffs. We show that the morphology of the coastal zone does not simply reflect the rate of tectonic uplift. It depends on several parameters that interact and that must be taken into account to decipher the tectonic signal highlighted by the presence of perched inactive cliffs.

Plant wax biomarker record from the Plio-Pleistocene site Guefaït-4.2 (Eastern Morocco)

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The earliest archaeological evidence from North Africa dates to ca. 2.4 Ma. Nevertheless, the palaeoenvironmental setting of hominins living in this part of the continent during the Early Pleistocene remains poorly-document, particularly in comparison to eastern and southern Africa.

The Guefaït 4.2 palaeontological site in the Aïn Beni Mathar-Guefaït (Jerada) basin of Eastern Morocco fills a crucial gap in the palaeoecology of North Africa, being correlated to the Plio-Pleistocene boundary based on biostratigraphy of large and small mammals and on preliminary magnetostratigraphic studies.

Here we present a new record of past vegetation and precipitation obtained from plant wax biomarker *n*-alkanes and their compound specific isotope analyses extracted directly from GFT paleontological site sediments. We provide a record of past hydroclimate and local vegetation dynamics, through the analysis of C_{25}-C_{31} *n*-alkane molecular indices (ACL - average chain length, CPI - carbon preference index, P_{aq} - aquatic plant ratio, and STR - submerged terrestrial ratio) and *n*-alkane δD and $\delta^{13}C$ values from the Guefaït 4.2 sedimentary sequence.

The plant wax biomarker distributions are dominated by odd-numbered, high- and mid-chain lengths, suggesting that both emergent and terrestrial plants contributed to the Guefaït 4.2 sediments, and that the mid-chain (C_{22}-C_{25}) and long-chain (C_{27}-C_{31}) biomarkers came from multiple biosynthetic sources. Additionally, changes in ACL, STR, and Paq show that the basin alternated between terrestrial and wetland habitats. The $\delta^{13}C$ data from C_{25}-C_{31} *n*-alkanes are fairly consistent throughout the stratigraphic column, ranging between -31.5 ‰ and -28.0 ‰ (-29.4 ± 1.0 ‰, n = 36) and revealing a C_3-dominant ecosystem. Hydrogen isotope measurements for the C_{29}-C_{33} *n*-alkanes range between -164.4 ‰ and -60.3 ‰ (-107.6 ± 20.3 ‰, n = 34), with isotope variability being associated with fractionation due to differences between plant ecological lifeforms and changes in local hydroclimate conditions.

The paleoecological data from GFT reveals diverse habitat types in the basin, ranging from grasslands, to woodlands, to wetlands. Meanwhile, increased water availability in the past seems to have allowed for diverse mammal communities to flourish in an area that today is dry and dominated by limited floral biodiversity.

Estimated paleotemperature through oxygen isotope analysis of Equus sp. teeth during Middle to Upper Paleolithic transition in central Italian site

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Rapid climate changes during the Middle-to-Upper Paleolithic (MP-UP) transition are considered one the most critical factors of the Neanderthal-Anatomically Modern Humans (AMHs) transition. These phenomena impacted population dynamics, fragmentation of optimal habitats, the deterioration of environmental conditions, and weakened local communities after the severe cold and dry stages. If compared to colder and less hospitable climate in northern and central Europe, the southern European peninsulas have long been considered refugia during periods of rapid climatic change in the Pleistocene. The Italian Peninsula mainly played a key role due to its geographical position (at the center of the Mediterranean) and broad environmental diversity. An accurate determination of the environmental conditions in the MP-UP transition is needed to understand the influential role of climatic change in the extinction of the Neanderthals in this area. In this perspective, evaluations of the high-resolution archives in tooth enamel from anthropogenically accumulated faunal assemblages are a welcome complement to the paleoclimatic proxies from oceanic and ice-core records. Oxygen isotope analyses of skeletal remains ($^{18}O/^{16}O$, $\delta^{18}O$) are a powerful tool for exploring past human-environment interactions and reconstructing paleoclimate and paleoseasonality. Here, we present phosphate-oxygen isotope ($\delta^{18}O_{PO4}$) data from horse (*Equus sp.*) tooth enamel (bioapatite) from the late Musterian, Uluzzian, and early Aurignacian find levels at the archaeological site of La Fabbrica Cave, Italy. Based on the relationship between obtained $\delta^{18}O_{PO4}$ of bioapatite, body water, local precipitation, and air temperature, these data have been used to estimate paleoclimatic conditions in different cultural phases during the neanderthal/sapiens transition. Sequential oxygen isotope measurements of enamel bioapatite phosphate ($\delta^{18}O_{Phos}$) formed complete or partial sinusoidal curves with summer (high temperature) peaks and winter (low temperature) troughs for teeth being studied. $\delta^{18}O_{PO4}$ values were then used to calculate $\delta^{18}O$ of local environmental water and mean annual air temperature (MATs) during the aforementioned phases of MIS3. This approach overcomes the problem of the scarcity of climatic information on short time scales in archaeological sites due to uncertainties in the chronometric dates, by providing direct estimation of mean air temperature at the precise time of their occupation.

Quantifying Heterogeneity in Hominin Environments In and Out of Africa.

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To understand Homo sapiens expansion we need to investigate the plasticity which has enabled our species' rapid dispersal. By investigating the environments which hominins adapted to throughout time we can better understand the origins of plasticity. By conducting a systematic review of published environmental reconstruction of Hominin sites in the early Pleistocene, we have found that during this period Homo was occupying heterogeneous environments. However, this heterogeneity appears to be distributed variably. At sites within the African continent the heterogeneity is within localities; outside of Africa the heterogeneity is between localities. To understand how plastic the niche Homo occupied in this period was we need to further investigate this heterogeneity and validate these findings.

To validate our finding of between locality heterogeneity out of Africa we have utilised mean ordinated hypsodonty of large plant eating mammals to investigate the environmental variability of the regions occupied by Homo during the early Pleistocene. Hypsodonty is a measure of tooth height and is an evolutionary response to increased dental wear. The increased wear associated with hypsodonty arises from several interrelated factors such as the proportion of grass in the food ingested, the occlusal pressure required to break the plant tissues and the dust load on the vegetation. The higher the mean hypsodonty of a herbivore community, the more open, grass dominated, and seasonal the environment tends to be. Our preliminary results show that the variance of mean hypsodonty across sites occupied by Homo in the early Pleistocene increased out of Africa, with the highest variance displayed in Asia. This supports the burgeoning hypothesis that Homo in this period was not constrained to the environmental limits of its African niche, but was increasingly able to exploit a wider range of environments.

A new record of a climate change in southeastern Spain during the cycle MIS 31–MIS 30, a key time for early human dispersal in Europe

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The Early Pleistocene Quibas-Sima sequence (southern Spain) represents the longest and most complete pre-Jaramillo to Jaramillo continental vertebrate succession in Europe. The age of Quibas-Sima was estimated to roughly 1.1–0.9 Ma for the whole sequence, immediately post-dating the oldest hominin record in Europe, as represented at the sites of Barranco León, Fuente Nueva-3 and Sima del Elefante. Quibas-Sima records a polarity change from a reverse interval (QS-1) to a normal one (QS-2, QS-3, QS-4) plus a second reverse one (QS-6 and QS-7). The normal polarity interval was identified as the Jaramillo subchron (1.07–0.99 Ma). Quibas-Sima is one of the very few palaeontological localities in Europe where the Jaramillo subchron has been certainly identified. This paleomagnetic interval characterizes the early phase of the Early-Middle Pleistocene transition, a time span that presents major changes in the Earth's climatic cyclicity. Moreover, this episode is particularly relevant concerning the earliest hominin occurrence in Western Europe. A significant change in the small vertebrate composition has been observed from the pre-Jaramillo QS-1 to the Jaramillo QS-4. Among the small mammals, this change involved the extirpation of species associated to woodland habitats and water bodies such as the flying squirrel *Hylopetes* and the water shrew *Neomys*. Among reptiles, it involved a shift towards species with a preference for dry and open areas, such as the snakes *Vipera latastei* and *Malpolon monspessulanus*. A paleoecological reconstruction using the Habitat Weightings Method based on herpetofauna suggests a progressive increase of open dry areas from QS-1 to QS-4. A bioclimatic model based on rodents points to a relative decrease in temperature and precipitations. Therefore, these methods point towards a progressive environmental change involving an increase in aridity, reduction of tree cover and spreading of shrublands in the onset of the Jaramillo subchron. This change is coincident with the transition from the warm MIS-31 interglacial (1.081–1.062 Ma) to the cold MIS-30 glacial. With this, Quibas-Sima becomes a reference locality to improve knowledge on the climatic events that occurred around 1 Ma at the Iberian Peninsula, as well as to increase our understanding of the paleoenvironmental context of early humans in Europe.

Early Pleistocene Environmental Conditions in the Levantine Corridor as Interpreted from a Multi-Proxy Study of a Sediment Core at ‘Ubeidiya: A Cornerstone for Understanding Early Hominin Migration

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‘Ubeidiya, central Jordan Valley in Israel (1.4 ±0.2 Ma), is a key site for studying Early Pleistocene hominin dispersal through the Levantine Corridor and is characterized by a rich faunal and lithic assemblage including hominin skeletal remains. The site was recently subjected to a renewed excavation aiming at producing a high-resolution chronology and reconstructing the environmental conditions that prevailed in the region. In 2021 we drilled a ~16 m core through ’Ubeidiya’s lowermost (and earliest) lacustrine cycle and subjected the pristine sediments to a set of sedimentological and geochemical analyses. The record includes a wide range of lithologies including carbonates, silts, massive clayey-silts, and well-preserved mm-scale clay laminae. Analyses included high-resolution magnetic susceptibility measurements coupled with elemental geochemistry and grain-size distribution. The results suggest that during the drilled time span, the lake experienced significant fluctuations in the associated depositional environments and lake-levels, ranging from prolonged low-stand episodes with massive carbonate deposits to a deep-lake setting characterized by oxic and sub-oxic conditions in the hypolimnion and deposition of finely laminated clays. Occasionally, the lake was affected by events inducing high-energy deposits (perhaps seismites or floods). Moreover, the measurements point to possible oscillations between a closed (endorheic) system to an open (exorheic) lake. This in turn might have left a great imprint on the mixing conditions and ventilation of the lake waters. Our contribution provides a solid basis for better understanding the different environmental settings and hydrological conditions that might have allowed early hominin migration in the Levantine Corridor.

Reconstructing the paleoenvironment of Southern Levant during Early Pleistocene using oxygen and carbon isotopic compositions in vole teeth

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The site 'Ubeidiya (Jordan Valley, Israel, 1.4 ± 0.2 Ma) is located on the major route of hominin dispersal from Africa to Eurasia during the early Pleistocene, and is one of the earliest sites to document these dispersal events outside of Africa. The role of arid vs. humid habitats in the dispersal of early *Homo* into the Levant has been debated. Therefore, quantitative, regional- to local-scale paleoenvironmental records in Southern Levant during Calabrian stage (1.8 – 0.77 Ma) may allow an examination of human-environment interactions during the time of their dispersal between the two continents.
To develop a modern model for the relationship between vole teeth and environmental variables in the Levant. We measured the stable carbon and oxygen isotopic ratios of modern Levant Vole (*Microtus guentheri)* teeth collected across Israel, and correlated these values to GIS derived temperature and precipitation data.
To reconstruct the past climate and vegetation compositions of Calabrian Levant we sampled teeth of the extinct vole *Lagurodon arnakae* from multiple strata across 'Ubeidiya. These were analysed for oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotopic compositions.
In comparison to modern Israeli voles, the Calabrian samples exhibit more negative $\delta^{18}O$ values (Mean = -2.4 ‰ ± 1.5SD) and more positive $\delta^{13}C$ values (Mean = -6.8 ‰ ± 3.8SD) than modern ones ($\delta^{18}O$ Mean = -1.4 ‰ ± 1.1SD; $\delta^{13}C$ Mean = -15.5‰ ± 1.3SD). A negative relationship was found between local rainfall amount and the $\delta^{18}O$ values of modern samples. Therefore, the isotopic signals of the Calarbian samples suggest a likely more humid environment in the past.
The results provide further insights into the climatic conditions which the hominin experienced when dispersing out of Africa and assessment of their adaptability to novel habitats. It lends support to the hypotheses that humid environments were significant in the dispersal of early *Homo* into the Southern Levant.

Vole mesowear and microwear as a novel proxy of vegetation structure: application in the early Pleistocene site of ‘Ubeidiya, Israel

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The role of the environment in *Homo* dispersal into Eurasia is debated.

The palaeoenvironmental context for early Pleistocene Homo dispersals in the Levant from multi proxy analyses of gastropod shells, Ubeidiya, Israel

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The Levant was a key corridor for hominin dispersals from Africa to Eurasia during the early Pleistocene. However, there is debate over the extent to which climatic fluctuations may have influenced these dispersals, and whether early Pleistocene *Homo* showed behavioural plasticity by adapting to different landscapes and environments, or simply took advantage of an expansion of grassland environments at this time. Whilst global and regional palaeoclimatic trends are well established, there is a paucity of local-scale palaeoenvironmental reconstructions associated with early Pleistocene *Homo* dispersals. The site of Ubeidiya, Israel contains some of the earliest evidence for hominin dispersals outside of Africa (1.4 ± 0.2 Ma) and a rich faunal assemblage including abundant *Melanopsis* spp. freshwater gastropod shells which enable local palaeoenvironmental reconstructions via multi-proxy analyses.

In this study we characterise the local environment and hydroclimate from Ubeidiya using geochemical and sclerochronological analyses of *Melanopsis* spp. shells sampled from the 1960-1999 Ubeidiya excavations. We analysed bulk and high-resolution sequential oxygen (δ^{18}O) and carbon (δ^{13}C) stable isotopes using both conventional isotope ratio mass spectrometry and sensitive high-resolution ion microprobe (SHRIMP), and clumped isotopes on bulk shells. The bulk analyses revealed that hydrological conditions fluctuated between wetter and drier conditions several times throughout both the older limnic inferior (LI) and the younger fluviatile inferior (FI) deposits, with clumped isotopes also indicating fluctuating temperatures throughout the sequence. *Melanopsis* shells grow continuously throughout the year, capturing the full range of seasonal variability. The sequential analyses revealed high amplitude δ^{18}O variability during the FI cycle at around 1.58 Ma, possibly indicating a more seasonal distribution of rainfall at this time. In agreement with other proxies emerging from this site, this evidence suggests that early Pleistocene *Homo* were not reliant on grasslands but were adaptable to new habitats and were resilient to significant palaeoenvironmental fluctuations. By providing local, high-resolution palaeoenvironmental context for the early Pleistocene Levant, this study facilitates a more nuanced understanding of early *Homo* dispersal patterns out of Africa.

Macrofaunal stable isotopes from 'Ubeidiya, Israel, shed light on environmental setting of an early presence of Homo in the Levant

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The spread of *Homo* out of Africa into new habitats represents a key process in our evolutionary history. Climatic fluctuations are thought to have played an important role in shaping such dispersals, but the niche and climatic tolerance of Early Pleistocene *Homo* remains poorly understood.
Here present we new evidence on the climatic conditions *Homo* experienced during the expansion out of Africa during the Calabrian (1.8-0.781 Ma) using stable isotope analysis of fauna from 'Ubeidiya, Israel (1960 – 1974 and 1988 – 1999 excavations). Due to its intermediate environmental character and geographical position between Africa and higher latitude Eurasia, the eastern Mediterranean could be considered a 'stepping stone' for dispersals of *Homo* in broader Eurasia. The site of 'Ubeidiya preserves one of the most important records of the Calabrian in this region (1.4 ± 0.2 Ma), encompassing a large palaeontological collection as well as *Homo* fossils. Bulk Oxygen (δ^{18}O) and carbon (δ^{13}C) stable isotope analysis from hippopotamus (*Hippopotamus behemoth*) and deer (*Pseudodama* sp.) teeth are used to generate semi quantitative data on relative aridity and vegetation structure. The comparison of a taxon tracking baseline hydroclimatic impacts on δ^{18}O (hippopotamus) with a taxon that tracks evapotranspiration in plant water (deer) means that aridity can be reconstructed while confounding baseline changes are controlled for. Using this approach, we document varying levels of water availability, including data on strata that have yielded fossil and/or implement evidence of the presence of *Homo*. The results exhibit a tentative trend of increasing relative humidity from the older limnic inferior (LI) cycle to the younger fluviatile inferior (FI) deposits. Overall, the data indicate a relatively humid environment with mixed C3/C4 vegetation with high proportion of C3 plants, indicating an absence of dry, open environments. This lends support to an increasing amount of data indicating that *Homo* was not necessarily dependent on open grasslands to expand into new habitats and underlines the importance of generating numerical climatic data directly from archaeological sites. Questions remain, however, about the seasonal distribution of rainfall and and additional work using sequentially sampled tooth enamel is needed to explore this further.

Geomorphology and lithology of Dakhla yardangs

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In many localities on earth and other solid planets, yardangs as the most spectacular aeolian landscapes. In the region of Dakhla (Morocco), yardangs are hills with a « teardrop » shape and a typical orientation NNE as it the orientation expressing prevailing winds. The conjunction of deflation and abrasion in a desert zone with sparse vegetation such as our study area, may be up the formation and evolving reliefs into these regular morphologies.

This study presents the first identification of the yardangs sculpted into Quaternary and Plio-quaternary formations during the Holocene in the Moroccan Sahara. In addition, this primary work focus on their geomorphological and lithological characteristics. The statistical results made on morphometric parameters provide valuable information for further investigations. Several data (lithology, topography, climate, etc.) and the comparison with other localities in the world have allowed discussing the factors and phases of the evolution of this wind erosion landscape.

Chronostratigraphic framework of a Middle Stone Age occupation at Oued Charef (NE Morocco)

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Within the framework of a long-standing multidisciplinary and collaborative investigation involving Moroccan and Spanish institutions, whose aim is to identify and contextualize evidence of Palaeolithic occupations in the Aïn Beni Mathar – Guefaït (ABM-GFT) region (NE Morocco), a Middle Stone Age site was found in 2006 in the outcropping sediment of the riverbanks of the Oued Charef (NE Morocco), a tributary of the Moulouya River. Archaeological excavations carried out in 2007 produced > 350 remains, largely dominated by lithic artefacts (97%), with a few additional burnt bones and charcoals. Interestingly, the lithic assemblage is dominated by flakes and cores, and numerous artefacts refits have been identified.

The sedimentary sequence is made of an about 5 m-thick succession of fluvial deposits associated to the Oued Charef. The archaeological horizon is located in a silty layer of the lower part of the sequence. While some previous studies suggested an Holocene age for the upper part of the sequence, the lowermost deposits have usually been assumed to be Pleistocene, although the absence of numerical age results did not allow any further chronological constraints.

In order to fill this gap, we used a combination of palaeomagnetism, Electron Spin Resonance (ESR) dating of quartz, Optically Stimulating Luminescence (OSL) dating of quartz, infrared stimulating luminescence (IRSL) dating of feldspars and U-series of bones. This multi-technique dating approach suggests that the archaeological horizon was deposited sometime during the MIS 5 interglacial complex, while this conservative interpretation of the existing data set might enable to refine this estimation to the late MIS5. These results convert Oued Charef into one of the very few, if not the only one, open-air MSA site in Morocco with robust age control.

Changes in the water level of Jili Lake in northern Xinjiang during the past 5200 years and its impact on the ancient Silk Road

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The rise and fall of the ancient Silk Road has always been the focus of both scholarly and public attention. This route, which facilitated cultural exchange and commercial trade between eastern and western civilization, crossed through one of the most inhospitable deserts in the world. And water resources were a crucial natural element that directly influenced human activity along the ancient Silk Road. However, there is still lack of research on the water resources variations along the ancient Silk Road, especially those available to humans. This study, we recovered the lake level changes of Jili Lake in northern Xinjiang during the past 5200 years, by analyzing the relative abundances of Hydroxylated glycerol dialkyl glycerol tetraethers (%OH-GDGTs) from sediment core. Our result show a gradual expansion of Jili Lake since 5200 BP, superimposed by significant centennial-scale water level fluctuations. By synthesizing records from other regions of Xinjiang, we recovered the relative changes in water levels in oasis lakes along the ancient Silk Road. The results reveal a general increasing trend of water levels in the oasis lakes since late mid-Holocene. During the past 2000 years, the water levels of oasis lakes reached record highs. The flourishing periods of the ancient Silk Road all coincide with periods of high water levels, while the interruptions and eventual decline of the ancient Silk Road correspond to periods of low water levels in the oasis lakes. Our research reveals that the water resources of oasis lakes in the desert played an important role in facilitating communication along the ancient Silk Road. It is worth noting that an inverse relationship between oasis lake levels and regional humidity on centennial-scale. During the warm period, the regional environment turns arid, while the water level of the oasis lakes rises, and vise versa. We argue that temperature-controlled snow and ice melt water played crucial role in driving oasis lake levels on centennial-scale. This suggests that we need to be careful to consider the distinction between regional humidity and the water available to humans, when exploring the role of water resources changes in the ancient Silk Road.

Human adaptation at the monsoonal threshold: Palaeolithic archaeology and Quaternary environments in western South Asia

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Western South Asia sits at the margin of the Indian Summer Monsoon system and is regularly hypothesised to have been placed on major routes of Pleistocene hominin expansion across Asia. This region coincides with numerous major thresholds that could influence human adaptation and expansion across western South Asia, including changes in geology, topography, climate and biogeography, and impact broader patterns of eastward dispersal. Examining Quaternary sediment archives presents an important means by which to examine how global patterns of climate change were manifest at this critical threshold, and thus the extent to which this landscape may have facilitated or prohibited human expansions, as well as presented a region that is favourable for long term inhabitation. Whilst western South Asia has a long history of Palaeolithic research, new fieldwork over the past decade has been transforming our understanding of the human occupations of this region and its significance for broader debates surrounding technological innovation, ecological adaptation, and hominin expansions and interactions. Here, we synthesise the results of recent studies of fluvial, aeolian and lacustrine archives of Quaternary environmental change with current examinations of the Palaeolithic record, focusing on Late Acheulean and Middle Palaeolithic sites.

Tales of Molar: Lingual-Labial Axis of Cercopithecidae molars as a proxy of Ecology and Diet in Late Pleistocene to Early Holocene Tropical Rainforests of Sri Lanka

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Sri Lanka's lowland rainforest caves, which have undeniable zooarchaeological materials consumed and discarded by prehistoric humans for over 48,000 years, hold some of the oldest fossils in South Asia. Among many taxa, Cercopithecids comprised about 20-25% of this fossil record, which can contribute to major themes of the island's prehistory, including hunting strategies and environmental change. This study aims to seek molar morphological differences among temporally synchronous but ecologically distinct groups by identifying morphologically disadvantaged species. Further, it attempts to underpin interpretive studies that aid contemporary biological and ecological studies and those concerned with adaptive changes through time due to environmental fluctuations. Molars can be a great indicator of diet variation, reflecting ecological adaptations.
The purpose of this study is to understand the difference between molars from two distinct groups of *Cercopithecidae* preserved in different geological epochs using morphometric analysis and statistical methods. The morphometric data was explored using Principal Component Analysis, Permutational Multivariate Analysis of Variance and Discriminant Analyses to evaluate inter- and intraspecific shape differences. The methods and theories proposed here provide ample information for understanding ecological selection and dietary preferences in the past. The results suggest a distinct pattern in the occlusal surfaces of the two clusters in the Cercopithecidae. The cusps of *Semnopithecus* were more denied, whereas the cusps of *Macaca* were enlarged in the lingual-labial axis. Therefore, taxonomic recognition established on molars, certainly on monkeys, is functional, especially with archaeological materials. Furthermore, geometric morphometric analysis has the potential to correlate changes in molar attributes in paleoenvironmental perspectives, phylogenetic variations, and morphological growth. The study is an effort to resolve the ongoing debate over the presence of the dry species *Semnopithecus priam* in Sri Lanka's Pleistocene Rainforests.
Keywords: *Cercopithecidae*, Geometric morphometrics, Osteology, Primate archaeology, Zooarchaeology

Looking for specific biomarkers of animal species to describe the development of the livestock

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Along the development of the domestication, rock-shelters and mountain caves have been used as stables for animals. During Neolithic and Chalcolithic ages the dung was piled it up and burned to eliminate the accumulated parasites and clean the space. This continuous behavior forms structures called *fumiers*. These remains are preserved under favorable conditions over time, being able to identify lipidic compounds in them.

The analysis of the biomarkers accumulated in those *fumiers* allows to know what species were stabled in those sites in order to obtain more information about the evolution of grazing. Nowadays, the analyses of lipids, such as sterols, phytosterols, and bile acids, are able to identify the origin of these organic remains using proxies obtained from contemporary samples. Nevertheless, these proxies supposes that the elimination or degradation ratios of these biomarker is similar for all of them, but really, there are not any research that corroborates this hypothesis.

Therefore, it is necessary to search for new biomarkers that make possible to distinguish these species clearly (pig, wild-pig, goat, sheep, cow, horse) without proxies or using more realistic ones and obtain clear information about the development of the livestock.

Consequently, in this research work, a high resolution mass spectrometry technique, such as liquid chromatography quadrupole Time of Flight, has been used for lipidomic analysis from animal faeces to find a specific biomarker for each animal species. Samples from goat, sheep, cow, horse, wild-pig and pig from different locations and diets were analysed. The results obtained were applied to facies collected from El Mirador cave in Sierra de Atapuerca, Burgos, Spain.

Lanoline residues on lithic blades to identify the beginning of sheep shearing: an experimental approach

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Sheep shearing represents the easiest way to remove the wool from the sheep to keep them cool in the warmer months and reduce the presence of parasites. This activity could have been started with the domestication of the sheep at the Neolithic ages and being the lithic blades the most likely shearing tool. Lanoline is a natural wax produce by the sheep and is accumulated in shearing tools during the cut. The remain of this wax in lithic blades could be a good biomarker of prehistoric sheep shearing. Therefore, the aim of this work was to determine if lanoline is a good biomarker of prehistoric sheep shearing in lithic blades.

For this purpose, four sheep of two different breeds, Latxa and Churra, from two different herds (Miñano, Araba/Álava, Basque Country, and Arlanzón, Burgos, Spain) were shorn using lithic blades (eight in total) for the characterization of lanoline residues remained in the blades. This remain was characterized extracting the total amount of lipids by ultrasound energy and analyzing them using analytical techniques such as gas-chromatography mass-spectrometry. In addition, optical instruments such as optical microscopy and environmental scanning electron microscope (ESEM) were used for determining the distribution of lanoline along the lithic blades and collect the sample more precisely.

In the future, these results will be used to identify shearing activity in Neolithic sites such as El Mirador cave in Sierra de Atapuerca, Burgos, Spain.

Lipid biomarkers at the Late Pleistocene open-air loess site Ollersdorf-Heidenberg (Austria)

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The period from 36,000 years ago towards the Last Glacial Maximum sees changes in environmental conditions with a general slow shift to a colder and more arid climate. The open-air loess site of Ollersdorf-Heidenberg (Austria) comprises a Gravettian archaeological horizon dated to around 29,000 years ago and two additional Upper Palaeolithic archaeological horizons. Rescue excavations in the 1990s and 2000s yielded rich lithic and faunal assemblages as well as evidence of charred plant matter. During new fieldwork at the site in 2017, 2018 and 2022 we used lipid biomarkers from sediments to assess anthropogenic activity and their environmental context throughout the sequence.

Our results show that (1) organic matter is well-preserved throughout the sequence, (2) the sequence preserves several stabilisation horizons in an open-grassland environment, which are sometimes accompanied with archaeological remains, and (3) brown lenses observed in the field comprise uncharred organic matter. No evidence of combustion activity could be detected through the lipid biomarker approach. We hypothesise that observed brown lenses are caused by an increase of organic matter input - potentially through anthropogenic activity - rather than the result of climatic improvement. These results are congruent with those from our soil-micromorphological and macroscopic geological analyses. The preservation of organic matter confirms the potential of Ollersdorf-Heidenberg for investigating human responses to environmental conditions.

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Residue analysis as a tool for reconstructing funerary and agricultural practices and vessel use history at the dawn of Egyptian history

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This paper will present results from organic residue analysis of an assemblage of funerary ceramics from ancient Egypt's Early Dynastic Period/early Old Kingdom (~3000–2600 BCE) from both royal and non-elite contexts. Owing to the restrictions in place on the exportation of archaeological samples from Egypt, this research has been carried out on material housed in international museum collections.

Absorbed and bulk organic residue analysis using both GC-MS (gas chromatography-mass spectrometry) and GC-C-IRMS (gas chromatography-combustion-isotope ratio mass spectrometry) has successfully extracted lipids from both sherd and intact vessel material. The results enable discussion not just of vessel use in funerary contexts but also of initial considerations of diet, subsistence, and animal husbandry during this period and through the lens of residue analysis, which has, to date, been severely under-utilised in Egyptian archaeology. Analyses will be presented alongside contemporary archaeological evidence from more recent excavations and in consideration of chronometric dating carried out on the material using a combination of radiocarbon and luminescence dating.

Dietary lipid residues and insights for land use and vegetation change

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A Late Holocene shift from forest to grassy vegetation on the eastern coastal plain, South Africa, has long been attributed to the agricultural activities of early farming groups. First millennium AD pioneers are suggested to have rapidly destroyed widespread coastal forests upon their arrival through slash-and-burn activities and the grazing of cattle. However, the ephemerality of early farming sites here, alongside generally poor organic preservation, means that we lack detailed information about the subsistence of these communities. This includes whether, and to what extent, cattle and other livestock were a part of early subsistence economies. Using lipid residue analysis, we investigate the molecular traces of foods preserved in the matrix of ancient cooking pots from Early Iron Age sites in KwaZulu-Natal, South Africa, from deposits that together span the first millennium AD. We assess evidence for the utilisation of dairy and other resources through time, and the implications for landuse and late Holocene vegetation change.

Lipid biomarkers and micromorphology of a Middle Paleolithic combustion structure from Axlor cave (northern Spain)

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Archaeological combustion features have been an important focus of research in the past decades. Stratigraphically, they may comprise a black layer representing charred soil matter beneath the fire, overlain by white or grey ashy layers associated with combustion activity. Microstratigraphic and biomolecular (lipid biomarkers) and isotopic analyses of these layers allows identification of combustion residues and substrate components to infer past fire-related activities and their environments. Here, we present the results of a biomarker, compound-specific and micromorphological study of a combustion feature from Stratigraphic Unit N at Axlor cave, a Middle Paleolithic site in northern Iberia. This Unit dates *circa* 100 ka. and contains abundant burned and unburned bones, charcoal, and lithic artefacts. Our molecular (n-alkane, aromatics, ketones, alcohols, and fatty acids) and isotopic ($\delta^{13}C_{16:0}$ and $\delta^{13}C_{18:0}$) analysis reveals good preservation of the organic matter and low temperature combustion. Micromorphological features point to an in situ human occupation surface with combustion residues postdepositionally stretched and deformed by mass movement. These data provide valuable clues about Neanderthal behavior and indicate high potential for organic geochemical analysis at Axlor.

Neolithic Human Diet Based on Studies of Coprolites from the Swifterbant Culture Sites, the Netherlands

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Coprolites are often referred to as the missing links in our knowledge of prehistoric diet and health. They offer direct evidence for dietary diversity and the consumption of food. They also mirror the health of ancient societies. A multidisciplinary approach was applied to study the Neolithic human diet. This research resulted in an extensive dataset including faecal steroid lipid biomarkers, micro-CT scans, SEM images, animal bone remains, phytoliths, pollen, intestinal parasites and starch granules. The results of this multidisciplinary project formed an extensive source of data for prehistoric dietary diversity and health. It also provided new insights into the Early Neolithic Swifterbant tradition and food culture.

Degradation patterns by thermoalteration of lipid biomarkers: an experimental case for tracking Neanderthal behaviour.

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The identification of anthropogenic signatures in archaeological contexts through preserved molecular markers requires an exhaustive previous experimental work to characterise the specific biomarkers involved in different activities from the anthropic occupation of natural spaces. The site of the Cueva Des-Cubierta Cave (Pinilla del Valle, Madrid), which has a symbolic interpretation, consists of an archaeological record characterised by an important collection of Mousterian lithic industry and abundant faunal remains - including an unusual number of horned skulls -, and is an ideal location to carry out this research.

The circulation of water and the complex sedimentary nature of the cavity makes it difficult to have a preserved archaeological record. However, the a priori recurrence inside the cavity of various activities related to the use of fire and the processing of skulls of large ungulates may have left a specific lipidic imprint in the sediment of the Late Pleistocene stratigraphic sequence.

The biomolecular characteristics resulting from this probable Neanderthal behaviour attempt to be defined in this work by analysing the patterns of abundance and distribution of the compounds found in the different lipid fractions (alkanes, aromatics, ketones and fatty acids) obtained in the exhaustive sampling of four replicative experimental hearths involving different variables and materials related to these activities (lithics, bones, speleothems and sediments).

Analytical techniques in biomolecular archaeology allow us to obtain quantifiable data on the preserved lipid compounds. The degradation and preservation of the different compounds detected in the lipid fractions involved in combustion provide us with reference data on a microscopic and molecular scale that will allow us to compare it with the profiles preserved in the archaeological samples in order to trace these Neanderthal activities inside the cavity documented on a macroscopic scale. Obtaining data relating to the stable isotopes preserved in both the experimental and archaeological samples will allow us to study in depth the environmental implications of this unusual archaeological context.

Domestication, diet and defecation: an integrated biomolecular and micro-contextual approach to archaeological faecal matter in sedentarising societies

Dr. Aroa Garcia-Suarez [1]***, Dr. Marta Portillo*** [1]

1. Spanish National Research Council

In this contribution, we present a multi-proxy study of settlement contexts from Near Eastern Neolithic sites aimed at securely identifying and analysing faecal matter from humans and animals, a material particularly prone to degradation. Out research integrates biomarkers (sterols and bile acids) with thin-section micromorphology and plant and faecal microfossil analysis to shed new light into herding practices, domestic uses of animal dung, foddering strategies, discard patterns, and human health.

Data from our earliest sites reveals the presence of herbivore faeces in combustion features, suggesting the use of dung as fuel might pre-date the development of cultural strategies of animal control. Results from later sites suggest shifts in the penning locations and grazing grounds of herds over time, likely a response to environmental changes. The identification of human faecal matter in open contexts points to the emergence of early sanitation practices at the dawn of sedentism.

Sensitive identification and quantification of food biomarkers in roman age ceramic pottery

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The use of the ceramic as storage or cooking recipient was a breakthrough for the daily life of human beings since Neolithic age and its study provides information about human behavior and evolution.
A useful tool for understanding better the consumed, stored, or transported food is the analysis of organic biomarkers from pottery. The porous structure of the ceramics provides the capability of accumulating persistent organic biomarkers for years. Thus, these biomarkers, such as fatty acids, sterols, phytosterols, *n*-alkanes,,,, can help to understand better the habits of the humanity due to the possibility to distinguish, for instance, between animal or vegetal fats.
This work presents the results obtained from the study of Roman age ceramic pottery from four different archaeological sites such as, Irulegi castle (Navarra, Spain) and Aiatzio, Esnaurreta and Argabi in Sierra de Aralar (Gipuzkoa, Spain). Wine, milk, fats (vegetal and animal fats), wax, resin, boiling ceramics and opium biomarkers were studied using a gas chromatography-mass spectrometry technique, after a one-step ultrasound extraction and hydrolysis.
Through this technique, SCAN mode was used for detection and identification of all the analytes. For qualification, an own library was built with the mass spectrum of each compound of interest. The identification of the compounds was carried out by the deconvolution of the chromatogram for each sample. However, the sensitivity of SCAN mode is limited, and more sensitive working mode must be carried out to detect some biomarkers. Therefore, the use of Single Ion Monitoring working mode can help us to detect those biomarkers not detected by SCAN mode.
In this study, a comparison between these working modes has been carried out. Thus, we observed that SIM mode is able to detect and quantify the analytes in a lower concentration which are not able to detect by SCAN mode.

Recent environmental changes around the cross-border channel of ‘’Gbaga”

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The “Gbaga” cross-border channel, a singular space because of its ecological importance and its geostrategic importance, is not on the sidelines of global changes that affect all regions of the world. In addition to the loss of natural resources, the consequences of its degradation have diplomatic aspects between the Republics of Benin and Togo. This research analyzes the recent global environmental changes in this space.
Climatic, hydro-morphological and land cover data are used. The diagnostic (statistics) and prospective (modeling) approaches made it possible to process the climatic and hydrological data. The diachronic analysis of satellite images and observational data is used to understand morphological mutations. Changes in land cover are examined using the mapping tool. Modeling according to several scenarios made it possible to predict possible future changes in the main environmental components.
The environment is characterized by rainfall instability and thermal warming with a high occurrence of floods and coastal erosion. The plant cover is degrading at an accelerated rate and the channel is gradually filling up. The changes affect more the coastline, freshwater ponds and marshes, mangrove ecosystems and the Beninese part is more affected. Anticipatory measures will have to be taken by Benin, which risks losing nearly 50% of its part of the territory by 2050.
Keywords: transboundary channel (Gbaga), climate change, coastal erosion, degradation of vegetation cover, sustainable management

Socio-economic and environmental impacts of the spatial evolution of temperature and dissolved oxygen in the fisheries of Lake Nokoue (southern Benin).

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Lake Nokoue, located in the South East of Benin, is shared by five municipalities belonging to three different departments. It includes hydro-ecoregions whose ecological characteristics favor significant colonization by fishery resources. The objective of this study is to contribute to a better knowledge of the socio-economic and environmental impacts of the spatial distribution of physico-chemical parameters (temperature and dissolved oxygen) in its various stations or hydro-ecoregions that constitute it.

Methodology and results: Data on physico-chemical characteristics were collected monthly from February 2017 to January 2018 in 20 fisheries integrated into Lake Nokoue. These main parameters such as dissolved oxygen (mg/l), temperature (°C), were measured by various appropriate devices. The spatialization of these physico-chemical parameters in the 20 surface and deep water sampling stations confirms the great variability of the factors depending on the weather and the hydrological area of the lake. Some variations are close to accepted tolerance thresholds for the survival of most freshwater and freshwater fish species.

The main results show that the different concentrations obtained are very close to the physico-chemical tolerance thresholds of certain species of fish or of the fishery resources living in the environment, specifically in areas with low human density. However, these same results also provide some insight into potential threats to the survival of aquatic species in areas of high human density. Lake Nokoue is experiencing serious environmental issues that threaten its existence and pose harmful risks to the populations benefiting from its goods and services. Threats related to this instability constitutes hazards that hinder the socio-economic development of the populations dependent on this lake and the retraining of the actors.

Keywords: Lake Nokoue, dynamics, spatialization- physicochemical parameters, impacts.

Drivers of the evolution and amplitude of African Humid Periods

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During orbital precession minima, the Sahara was humid and more vegetated. Uncertainties remain over the climatic processes controlling the initiation, demise and amplitude of these African Humid Periods (AHPs). Here we study these processes using a series of transient simulations of the penultimate deglaciation and Last Interglacial period performed with an Earth system model of intermediate complexity (LOVECLIM). These results are compared to a transient simulation of the last deglaciation and Holocene. We find that the strengthening of the Atlantic Meridional Overturning Circulation (AMOC) at the end of deglacial millennial-scale events exerts a dominant control on the abrupt initiation of AHPs, as the AMOC modulates the position of the Intertropical Convergence Zone. In addition, residual Northern Hemispheric ice-sheets can delay the peak of the AHPs. Through its impact on Northern Hemispheric ice-sheets disintegration and thus AMOC, the larger rate of insolation increase during the penultimate compared to the last deglaciation can explain the earlier and more abrupt onset of the AHP during the Last Interglacial period. Finally, we show that the mean climate state modulates precipitation variability, with higher variability under wetter background conditions.

Finding Suitable Grounds: Early crop cultivation in the lagoonal-deltaic landscapes of the Netherlands

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During the Mesolithic-Neolithic transition, the adoption of crop cultivation by the inhabitants of what is now the Netherlands faced a dynamic wetland environment. Meandering fluvial channels, rising sea levels, and repeated flooding in lowland areas produced a landscape with variable suitability for farming. Under such conditions, in both lagoonal lowlands served by small rivers and the deltaic setting served by branches of the river Rhine, it appears incipient farming was restricted to specific landscape niches.

Early and Middle Neolithic Swifterbant culture sites (6000-4000 BCE), including settlements, burials, and tilled fields have been found on contemporary levee features. These riparian zone land surfaces with short-lived fluvisols were locally cleared to establish fields and have been buried and submerged by subsequent deposition, resulting in excellent preservation of the sites and off-site soils. This offers a great opportunity to study human subsistence and the transition to agriculture in the back-barrier coastal plains along the North Sea. In the “Finding Suitable Grounds” project, we sample these strata in the Rhine delta and the Netherlands’ central lagoon and investigate them geoarchaeologically and archaeobotanically to place the actual agricultural activities within the landscape surrounding known settlement sites.

Repositories of previously collected regional palaeolandscape information (which includes decades of coring, mapping, and palaeoenvironmental characterization of the Dutch subsurface), in addition to newly available geophysical data, enable us to target and sample a swath of river channels active during the Early to Middle Neolithic. Micromorphological samples from these cores are used to identify soil formation, flooding frequency, and potential anthropogenic disturbances of the natural levee sedimentation sequence, including indications of clearing, burning, and tilling. Parallel research uses the same cores for botanical proxies, ^{14}C dating, and geochemistry. By applying this detailed multi-faceted analysis to a regional-level landscape study, we aim to understand if, where, and for how long suitable soil conditions for early cultivation were present in the Dutch wetland environments during this transitional period. And if so, whether thin-section micromorphological analysis reveals evidence for human subsistence activities that would not be otherwise visible.

The micromorphology of iceberg-keel scoured diamictons from the Bellingshausen and Amundsen Seas: An approach to improving reconstructions of West Antarctic Ice Sheet extent

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In the past the West Antarctic Ice Sheet (WAIS) extended beyond its present-day limits, sometimes as far as the continental shelf edge during e.g. the Last Glacial Maximum (LGM, ~19-23 ka). Sediment deposited at the base of grounded ice is known as subglacial diamicton (or 'till'). In addition, diamictons can be formed in a range of other glacimarine depositional environments including sub-ice shelf or seasonally open marine settings, as iceberg rafted and scoured diamictons, or glacigenic debris flows. Whilst there has been some progress in characterising subglacial and iceberg scoured diamictons at both macro- and micro-scales, historically it has been difficult to distinguish between different types of diamictons formed in very different settings. This is particularly true for areas where several glacial and glacimarine processes operate, and thus, overprint each other. However, distinguishing between the different types of diamictons is crucial if we are to reliably reconstruct the maximum extent of the WAIS in the past and the timing of its retreat. This information is urgently needed for ice sheet and climate models that are used to predict future WAIS changes and resulting global sea-level rise. The aim of this study is to macro- and microscopically examine, and determine the origin of, diamictons from the outer shelves of the Bellingshausen (core GC371) and Amundsen Seas (cores VC430, VC436), in West Antarctica. Although the three cores examined in this study were retrieved from sea floor areas affected by iceberg scouring, their diamictons may also represent any or all of the other aforementioned diamicton-forming processes. Micromorphological analyses show that diamictons in all three cores have undergone stress resulting in pervasive deformation subsequent to deposition. Cores GC371 and VC430 contain diamictons with more abundant and better developed microstructures than core VC436, indicating more intense deformation than in core VC436. Micromorphological structures in all three cores demonstrate complicated and/or inverse downcore deformation patterns, which often do not complement a traditional strain profile. This indicates potential overprinting of structures at several horizons after multiple deformation events. Future research should focus on attempting to identify and unravel separate deformation events in Antarctic diamictons.

Sand, hearths, lithics, and a bit of bioturbation: Micromorphological investigations at Umhlatuzana rockshelter, South Africa

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Umhlatuzana rockshelter is located in KwaZulu-Natal, South Africa and demonstrates a virtually continuous archaeological record throughout the Middle Stone Age, Later Stone Age, and Iron Age (~70,000 years BP to present). We conducted multi-proxy geoarchaeological analyses (micromorphology, XRD, SEM-EDS) to reconstruct the depositional and post-depositional history of the site. The Pleistocene deposits appear macroscopically homogenous but micromorphological analysis revealed depositional, unaltered micro-layering throughout the sequence. Sediments related to combustion activities are observed throughout the sequence although the preservation conditions appear much better in the Holocene. Post-depositional geochemical alterations resulted in the formation of phosphatic minerals that affect the site's taphonomy. One of those phosphates is vashegyite, a rare magnesium-phosphate mineral associated with acidic and moist sedimentary environments. Although bioturbation features are evident, sediment mixing does not seem to affect the vertical distribution of the artefacts meaning that the lithics can be analysed as coherent assemblages.

Compositional, micromorphological and stratigraphic characterization of Holocene Tiber floodplain deposits (Rome, Italy)

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The sequestration of sediment deposited on alluvial floodplains may release an identifiable fingerprint on sediment composition and texture. In this regard, soil micromorphology, can be used to better discriminate the role of autocyclic and long-term factors in controlling the environmental condition of soil formation when framed into Quaternary stratigraphic record. In this study, we report a high-resolution micromorphological characterization of the Holocene Tiber River floodplain soils for a better understanding of the soil processes related to changes in water table, biological activity, weathering, and accommodation space and integrate soil micromorphology with sequence stratigraphy. Petrographic and micromorphological features from a borehole advanced 60 m into the Tiber channel belt and floodplain, document incipient pedogenetic modifications across stratigraphic markers evidenced by faunal and plant activity, accumulation of peat, and typified by precipitation of heavy metals, iron oxides and secondary carbonates. All these features developed in correspondence of surfaces of stratigraphic significance and reveal depositional features and post-depositional modifications associated with different environmental changes. These observations tell us about a specific history case of incipient soils formation in the Late Pleistocene to Holocene Tiber Depositional Sequence but may serve as a model to reconstruct the stratigraphic evolution of ancient relict soils in similar alluvial settings. This work demonstrates that a combination between sedimentological and stratigraphic observations and soil micromorphology can be critical to supplement field observations and determine the relative effect of pedogenic and depositional processes on the organization, composition and texture, and geotechnical properties of floodplain in urban areas.

Investigating duricrust diagenesis through high-resolution petrographic and geochemical methods

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Duricrusts are surficial biogeochemical deposits that are recognized as a significant repository of information to study paleoclimate and paleoenvironments. Multiple mechanisms at different diagenetic stages are involved in duricrust formation, resulting in various types of fabrics and shapes. While diagenesis in duricrusts is commonly apparent, diagenetic processes in continental settings and their products are challenging to differentiate, leaving their variability and signature on geochemical and geochronological proxies far from being fully understood.

We use optical and cathodoluminescence petrography coupled with high-resolution elemental analyses to study the diagenetic history of duricrust deposits from the Kalahari Basin in southern Africa. We construct a relative chronological framework of duricrust formation, which is based on a visual investigation of various shapes, textures, and relationships of the cements with the host material. By disassembling the various mechanisms involved in the diagenesis of the cements through investigating their geochemical proxies, we link various diagenetic processes occurring during duricrust development with the different environmental settings that trigger these processes. This framework is tested against what is known for the paleoenvironmental conditions that prevailed across the Kalahari during the Quaternary.

Morphological analysis of mineral grains from different sedimentary environments using automated static image analysis

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The transport mechanisms of different geomorphological and sedimentary environments are reflected by the grain shape properties of the sediments. The spread of new, high-resolution analytical methods has made it possible to examine grain shape properties quickly and by large number of observed individual mineral grains. We investigated mineral particles of three sediment types from different depositional environments (wind-blown sand, floodplain and channel deposits, infilling material of sand wedges, [n=20]) from the Carpathian Basin (Central Europe) by using automated image analysis (Malvern Morphologi G3-ID). Our vital aim was to determine the key variables that can help us to distinguish certain geomorphological environments. During the analysis and data processing (e.g. hierarchical cluster analysis, Wilks' λ, Kruskal-Wallis, MANOVA, PCA) we examined four variables related to grain shape which were the following HS circularity (form), convexity (surface texture), solidity (roundness) and elongation (form).

The objective and quantitative study revealed that distinguishing between geomorphological environments can be made based on HS circularity, convexity and solidity parameters of the sediment grains. According to univariate and multivariate statistics, HS circularity is the most effective attribute and the elongation variable proved to be the least influential parameter on differentiating sedimentary environments. The transport distance can be inferred from the HS circularity parameter. The transport energy can be obtained from the solidity parameter. The convexity parameter can be used as the indicator of transport distance, energy and post-depositional processes.

Some sand wedge materials underwent at least two transport processes in a high energy aqueous, wind transport mechanism and a post-depositional alteration process (frost weathering), while others originated from sand-sheet covered areas (active during Pleistocene glacials).

Solidity parameter proved to be an effective variable on separating sediments that had similarly high convexity values (smooth surface) which were in our case from aeolian and fluvial environments. Our research support that aeolian transport is more effective in rounding the grains than aqueous environment.

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Micromorphological insights within the Middle Pleistocene-Holocene cave sediment record of Grotta Romanelli, Italy

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Approaching the sedimentary and anthropogenic input within fine-grained or very fine-grained sediments in caves can be improved by micromorphological investigations. In fact, weakly developed sedimentary structures or apparently massive structures often characterize human settled cave environments and the microscale information is of paramount importance for the determination of the sedimentary and geomorphological context.
Grotta Romanelli offers a unique chance to correlate the Middle Pleistocene (ca. 350 ka BP) to the Early Holocene (ca 11 ka BP) human frequentation with the sedimentary processes and the origin of the sediments that filled progressively the cave. The micromorphological investigations were carried out on the fire-related Middle Pleistocene levels on top of coarse-grained marine in-cave deposits and on the silty-clayey and sandy clayey Late Pleistocene-Holocene layers.
Micromorphology revealed several microfacies associated with the finer-grained sediments. The in-cave sediments are of external origin, as indicated by the abundance of aeolian quartz and pedorelicts of leached soils that were eroded and transported within the cave. The microfacies analysis indicates run-off and standing water processes and redistribution within the cave of the external sedimentary input, including phases of biological activity and related relative surface stability and anthropogenic inputs. The anthropogenic input is not linked to specific areas and locations within the cave, mostly due to the dimensions of the cave itself and the volume of already excavated sediments in historical archaeological digs in the mid-frontal sector of the cave. Therefore, anthropogenic materials are sparse within the different microfacies and consists of evidence of use of fire and food activities (burnt bones, charcoals, charred plant tissues etc.).

Soil Micromorphology of Agricultural Terraces in Europe

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Agricultural terraces are an important factor in the development of agriculture, allowing for expansion, intensification, diversification and even specialization. To date, the archaeological study of these fossil agricultural landscapes has been slow, hampered largely by difficulties in disentangling the complex chronologies generated by the construction, use, management, and abandonment of agricultural terraces. Despite this, the understanding of soil development on terraces remains an integral part of reconstructing past subsistence and understanding the impact of the terraces themselves on the soils, the crops, and ultimately the socioeconomic systems they helped to support.

This poster presents the preliminary results of soil micromorphological analysis of agricultural terraces from 10 sites across continental Europe, ranging from sub arctic conditions to dry Mediterranean conditions. Samples were taken from terraced soils representing agricultural activity ranging from roughly 1600 BCE to 1900 CE, and encompassing such common crops as potato, grains (wheat and barley), and vines (winemaking). Photomicrographs of fabric and features generated through the agricultural reworking of the soil are presented here, alongside evidence from elemental and molecular analysis via pXRF and FTIR. The depositional and pedological features presented are also assessed via pOSL, to understand the relative chronologies of the accumulation and in situ development of terrace soil features. This research is hoped to provide a new geographically extensive record of soil microfeatures related to agriculture and agricultural terraces in particular.

Floodplain dynamics, natural resources and human settlement change from the Archaic to the Postclassic in the Basin of Mexico.

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The endorheic Basin of Mexico (BM) is characterized by a heterogenous landscape that comprises volcanic and tectonic structures, and a diversity of depositional systems that include glacial, alluvial, fluvial, eolian and lacustrine sediments. The alluvial plains around Lake Texcoco are complex features formed by medium to low order fluvial drainages. Additionally, the structure of these plains is complicated by the influence of springs and wetlands, many of which are associated with archaeological sites of various periods. The proposed work aims at studying landscape evolution of floodplain areas in tandem with human occupations spanning the pre-ceramic, agricultural, and the Aztec periods on the eastern side of Lake Texcoco. In addition, we will study how humans transformed the environment to implement diverse subsistence strategies. A paleolandscape reconstruction will be performed using the floodplain sediments of San Bernardino and Chapingo fluvial systems as natural archives and the archeological record from the pre-ceramic burial site of the Texcoco Man. A GIS model was constructed to analyze the landscape attributes that influenced the fluvial dynamics. Based on this model and field surveys, we selected six different locations between the San Bernardino and Chapingo fluvial systems, to perform a series of test pits. The preliminary results reveal that the lower section of the sedimentary sequences comprises a series of muddy facies with a high content of calcium carbonate according to the p-ED-XRF and XRD results, with a minimum age of 3373-3221^{14}C cal yr BP. The upper facies are formed by intercalation of silty and sandy facies partly interrupted by the formation of soil horizons and with a maximum age around 2258-2156 ^{14}C cal yr BP. Thus, our preliminary results suggest a regression phase Lake Texcoco during the beginning Meghalayan stage of the Holocene, accompanied by a sequential progradation in the fluvial system towards the lake. We hypothesized that sequential lake regressions and transgressions in conjunction with fluvial activity and spring activity produced a rich environment full of natural resources. In consequence, this landscape was attractive to the establishment of diverse human groups and settlements.

Human-environment interactions in the Gete catchment (Belgium). An interdisciplinary approach.

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Floodplains are highly dynamic environments that have attracted humans throughout history. They have been shaped by the interplay of geomorphological, ecological and hydrological processes, as well as directly and indirectly by human activity. It is in these parts of the landscape that we find ideal research areas to study and reconstruct human-environment interactions from a long-term perspective. For this paper we will focus on one such area: the Gete catchment.

Geomorphological and palynological research shows that floodplain geo-ecology underwent a gradual transformation from a marshy wetland environment to a stereotypical alluvial floodplain. A change that was initiated already around 5000 to 4000 BP, roughly 2000 years earlier than other studied floodplains in the Belgian loess belt. This difference in timing can be explained through the long agricultural history of this specific catchment, which starts with the arrival of the first farmers in the Early Neolithic and runs like a thread through its evolution. Archaeological and historical sources are studied and integrated at a catchment scale to increase insight in key aspects of this history: changes in population size and density along with changes in subsistence- and land-use strategies.

This approach provides us with a high-resolution reconstruction of the effects of increasing and decreasing human impact on floodplain geo-ecology. Not only in relation to the start of the aforementioned transformation, but also the speed at which it took place, when it was completed and signs of within-catchment variability. As such the data is not only illustrative of the effect humans had on their environment, but also of environmental resilience: changes in floodplain geo-ecology only occurred when changes in human impact were large enough and reached a certain threshold. This can have important implications for future floodplain management. By taking into account the past, it will not only enable us to understand how the present-day landscape came about, but it can also learn us lessons to adapt and employ towards a more sustainable future.

Palaeoecological Evidence for the Domestication of the Wetlands of the Bolivian Amazon.

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Recent palaeoenvironmental reconstructions of Amazonia have shifted our understanding of past human manipulation, or 'domestication', of the landscape. Evidence includes extensive earthworks, ancient field systems and alteration of forests for economically useful taxa. Most studies have focused on terrestrial landscapes, with few investigating the impact on aquatic ecosystems.

The Llanos de Mojos is a 135,000 km^2 sub-basin of the Bolivian Amazon characterised by a strong annual flood cycle and a forest/savannah/wetland mosaic. Pre-Columbian earthworks have been identified throughout the Mojos which are hypothesised to have controlled the annual flood cycle. Examples include raised fields, forest islands, fish weirs, and causeways. Construction of earthworks are integral to socio-environmental interactions of Pre-Columbian societies, which then impacted components of ecosystems within the Mojos.

The Quinato Wetland (13°38'45.7"S, 65°35'03.8"W) is a permanent wetland situated within a ca. 320km long palaeoriver channel surrounded by raised fields, forest islands and fish weirs. Previous palaeoecological investigations of two sediment cores (QM, ME) extracted from areas adjacent to forest islands demonstrated landscape domestication began at least 3500 yrs ago with evidence for local hydrological management and fire use, implying terrestrial and aquatic resources were managed concurrently. Evidence for establishment of permanent wetlands at both sites suggests fish weirs were the mechanism which managed the floodwaters.

This study aims to characterise domestication of the wetland and associated ecological impacts through new palaeoecological analysis of existing (QM, ME) and new (LA, MI) sediment records using a multiproxy approach (charcoal, diatoms, pollen, invertebrate remains and organic geochemistry). Basal ages of the cores range from 7460–1230 yrs BP. Through diatom and aquatic pollen analysis on MI (located adjacent to a fish weir) we test whether its construction was the mechanism which controlled local wetland floodwaters. Wetland domestication is hypothesised to have enabled better management of aquatic food resources (e.g. fish). Through aquatic ecology indicators (invertebrate remains, aquatic pollen, diatoms) and organic geochemistry analyses, newly applied to this region, we will investigate the impact of wetland manipulation on ecology and biodiversity. The results will highlight the legacy impact of past domestication on wetlands today; increasing our understanding of water-human-environment interactions in tropical regions.

Geoarchaeological study at the “Kakoryca-4” archaeological site (Southern Belarus)

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The archaeological site “Kakoryca-4” is located on the territory of Belarusian Polesie, in the basin of the Yaselda River and Lake Sporovskoye, beyond the border of the last glaciation. Vast area around the studied site is occupied by meadows and wetlands. Most of the archaeological finds from the “Kakoryca-4” is dated to the Neolithic and Bronze Age (V–II millennium BC), and attributed to the following cultures: Pripyat-Neman and Neman Neolithic cultures (V-III millennium BC); the Corded Ware culture circle and Epi-Corded Ware culture horizon (middle of the IIIrd - beginning of IInd millennium BC); Trzciniec cultural circle (II millennium BC).
The presented in this paper sediment cores were collected in the surrounding of the archaeological site. They were studied using spore-pollen, carpological, radiocarbon, sedimentological, geochemical analyses, as well as archaeological research methods. The collected sediment cores were of Late Glacial and Holocene age. The Late Glacial deposits were predominantly mineral and consisted of sands, as well as calcareous and non-calcareous gyttja. In turn, the Holocene deposits were predominantly organic and consisted of gyttja and peat.
The obtained results allow for the palaeoecological reconstructions for the studied area, mostly: regional and local vegetation reconstruction, fluctuations in the size of Lake Sporovskoye, the stage of increased fluvial activity of the Yaselda River, sedimentation changes in the Late Glacial and Holocene. The study of the archaeological data revealed the history of functioning of human communities and their survival strategies. The correlation of palaeoecological and archaeological data allow for deeper study on human-environment relationships since the Stone Age in the Belarusian Polesie.

Multiple approach in palynological analyses to characterize human / environment dialectic in lakeshore environments: new data from the emerged sector of the early Neolithic site of La Draga (Banyoles, Spain).

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The spread of farming lifestyle is considered a key point in the debate on early human impact on environment and climate in the past, and the beginning of the Anthropocene. The Early Neolithic lakeshore settlement of La Draga, dated between 7270 and 6750 cal. years before present (BP), represents the oldest known archaeological evidence of farming societies settling in a lacustrine environment in the Iberian Peninsula. Previous pollen analyses in both the lacustrine record of Lake Banyoles and the archaeological waterlogged sequence evidenced for the first-time human modification of the landscape through broadleaf deciduous trees deforestation at a local and regional scale in north-eastern Spain. New palynological data from the emerged sector (Sector A) of the settlement brings new interesting results to the debate. Our increasing knowledge of the vegetal landscape of the Neolithic community points toward a stronger impact of human activities locally, resulting in a clear dominance of non-arboreal vegetation, in particular ruderal herbaceous taxa and crops around the settlement: in the emerged sector, the maximal human imprint on the landscape was recorded corresponding to the second phase of occupation (between 7100 and 6700 cal. years BP). Spatial analyses applied to palynological data in Sector A has proved useful in determining patterns of social use of space linked to plant management activities, and patterns of taphonomical alteration of the record. Most of the horizontal variability of the record is explained by human activities such as crop storage and processing, and taphonomical processes linked to subaerial clay sedimentation that altered the preservation of pollen and the development of fungal organisms. Still, results support the critical importance of non-pollen palynomorphs identification and interpretation to understand taphonomical and anthropic processes that impacted the pollen assemblage. This multiple approach, integrating the traditional palynological methodology as well as intra-site spatial analyses, multivariant statistics, and non-pollen palynomorphs, allows to draw a complete interpretation of the palynological assemblage in an archaeological site at a paleoenvironmental, taphonomical and cultural level. Integrated palynological analyses in wet environments thus represent a valuable approach to understand the dialectical relationship between past human societies and natural environment.

Late-Holocene climate change and the cultural landscape of Weipa, Australia

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Weipa, on the western Cape York Peninsula of Queensland, Australia, has long been a hot spot of archaeological research due to its rich cultural history that stretches back over many thousands of years. Sites of archaeological interest include shell mounds, earth mounds, scarred trees and stone artefacts. Recent studies on the shell and earth mounds at Wathayn, south of Weipa, have shown that shell mound activity was concentrated between 2500-2000 cal. years BP, while earth mound building commenced after 2200 cal. BP but was most prevalent over the last 500 years. Palaeoecological data can potentially provide the environmental context surrounding these changes currently missing from archaeological theories and narratives.

This study reconstructs the environmental history of Bellevue Creek Swamp and the surrounding landscape south-east of Weipa, over the last 6400 years based on the analysis of pollen and charcoal extracted from sediment cores. This late-Holocene record shows that swamp initiation began after 5000 cal. BP and that permanent running water existed from approximately 2200 cal. BP until after 150 cal. BP when anthropogenically forced changes on the landscape transformed the swamp surface to a sedgeland. The surrounding eucalypt woodland remained essentially stable for the period from 6400-150 cal. BP. While a regional fire signal is present throughout the record, only one pronounced period of localised burning is recorded, occurring over the last 150 years. The hydrological change to a wetter environment and permanently running water that occurred after 2200 cal. BP overlaps with the end of intensive shell mound building and the beginning of earth mound building at nearby Wathayn.

It is suggested that suboptimal conditions for shell beds arose with the increase of freshwater into the system after 2200 cal. BP. Parallel to this, a wetter environment likely expanded available resources located further inland at Weipa, and around the creek lines themselves leading to the building of earth mounds. This study highlights the importance of palaeoecological studies to build an environmental context for archaeological interpretations.

The impact of Early to Middle Bronze Age settlements and farming on vegetation, ecology, nutrient flux and sedimentation at Lake Lucone, northern Italy

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We produced an integrated history of terrestrial and lake ecosystems from a high-resolution stratigraphy from Lake Lucone, a small, closed lake, in the Prealps of northern Italy, which is characterized by predominantly endogenic, biologically controlled sedimentation covering the last 5500 years.
Our analytic approach combines ordination techniques with time series analysis to detect correlated changes among microbotanical variables (upland and aquatic pollen, algae, cyanobacteria, dung spores, microcharcoal particles), sedimentary proxies (LOI steps, calcimetry, FTIR spectrometry) and main nutrients, which are stable under waterlogged conditions (P_{inorg}, P_{org}, K).
The impact of the Bronze Age pile dwelling is recorded by massive effects on terrestrial ecosystems, lake sedimentation, and nutrient influx. Forest conditions and lake sedimentation returned to semi-natural baseline at the end of the 700-year long phase of Early to Middle Bronze Age settlement, but lake-side forests did not fully recover, and further changes on landscape composition occurred from the Iron Age onwards. Time series correlation of micro-botanical proxies and P forms have enabled to detect different patterns of human impact, and the contrast of internal and external P sourcing. During the dwelling phase intensive P mineralization, produced by fireplaces triggered P_{inorg} sinking. P_{inorg} was promptly immobilized by calcite absorption, thus preventing blooms of green algae and cyanobacteria. Analyzing waste disposals, we could also distinguish domestic hearth production from a contribution by animal husbandry, the latter marked by P_{org} increase. External sourcing was prompted by farming and cropping in the lake catchment. The observed changes, in littoral sedimentation and biological proxies in the 5500-years long sequence, are primarily affected by human impact. Lake Lucone represents a key site, since it documents interactions between bronze Age settlements and related ecological impacts on both terrestrial environment and lacustrine sedimentation, as recorded in a continuous sequence, as well as the end of Bronze Age pile dwelling culture.

Mountainous vegetation succession in the Peloponnese (Greece) during the last two millennia

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The significant regional topographic and climatic variability, along with human activity are the main shaping factors of the vegetation development in the Mediterranean. In particular, the mountain ecosystems and their valuable natural resources have long been attractive to human societies. The Peloponnese (southern Greece) has been the scenery for development of numerous human communities. So far, the existing paleovegetation records from the Peloponnese derive from lowland sites, while the vegetation succession of the mountains is not clearly understood.

Located on Panachaiko Mountain, the Rakita wetland preserves an exceptional archive of the vegetation succession. A detailed palynological analysis of the deposits was conducted at a mean 20-year temporal resolution and the age-depth model is based on 9 AMS radiocarbon dates. Whereas the Rakita area has been inhabited since the Mycenaean times, robust demographic data are available only after the mid-15th century CE. Ottoman and Venetian population surveys show that a number of small and medium-sized settlements existed in the area.

The well-preserved pollen assemblages accompanied by NPPs highlight significant shifts in the vegetation during the last 2000 years. Our record provides the first insights to the plant landscape evolution from the upland Peloponnese. The base of the sequence is characterized by open vegetation, while the deciduous *Quercus* woodland and the coniferous forest components, such as *Abies* or *Pinus* appear restricted. The concurrent high abundance of Cerealia-type and the presence of weed species, feature an interval of significant anthropogenic activity in the area, corresponding to the Late Antiquity. Following, the increase of deciduous *Quercus* and the drop in all human pollen indicators mark the expansion of the deciduous oak forest and the retreat of human pressure on the mountainous environment during the Early/Middle Byzantine. At the beginning of the Late Byzantine Period a sharp opening of the deciduous forest is evidenced, while the expansion of Cichorieae and other ruderal taxa underlines pastoralism as the main human activity. During the Ottoman period, the moderate expansion of the deciduous forest and the amplification of evergreen maquis showcased the introduction of sustainable land use practices during an interval of increased population in the area.

Vegetation and land-use history of the 'Kromme Rijn' area near Utrecht (Netherlands) during Roman and medieval times

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The river 'Kromme Rijn', part of the Rhine in the centre of the Netherlands, has witnessed important historical events over the past millennia. In Roman times, the river served as border of the *Lower Germanic Limes*, the northern border of the Roman Empire. After the Dark Ages, the settlements Utrecht and Dorestad thrived along this part of the Rhine. To prevent the risk of flooding and to gain new lands, Bishop Godebald of Utrecht ordered the damming of the Kromme Rijn in 1122 AD, after which the river reduced in size but remained an important transportation route. How did these historical events affect landscape and land-use in the Kromme Rijn area? To reconstruct past vegetation and land-use of the Kromme Rijn area near Utrecht the infill of a residual channel has been studied. This residual channel was a meander, cut-off from the active river system in the Roman period. The c. 3m thick undisturbed channel fill encompasses Roman to late medieval times and includes the moment of embankment. High-resolution Loss on Ignition and palynological analyses have been performed to reconstruct depositional processes and changes in local and regional vegetation. In addition, other palynomorphs have been studied as indicators of water quality and human activities. The records reveal increasing openness of the landscape, interrupted by a phase of apparent reforestation. Opening of the forest cover is an indication for periods of human activity. The presence of cultural indicators such as pollen of cereals, and later buckwheat and cornflower, indicate agricultural activity in the near surroundings.

The Bisenzio Project: transdisciplinary investigation strategies to reconstruct human and palaeoenvironmental history of the Bolsena Lake (Central Italy)

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The Bisenzio Project focuses on reconstructing human-environment relationships at the Bisenzio archaeological site. The ongoing research combines scientific methodologies, archaeological procedures, and field techniques, aiming at integrating past socio-economic dynamics into a broader perspective of long-term environmental changes.

Three continuous sediment cores were collected up to 20 meters deep in the alluvial plain bordering the archaeological area. Lithostratigraphic analyses were carried out to characterize depositional facies and outline the evolution of the depositional system in relation to lake level oscillations. The sediment fractions were further examined for the recognition of microfauna and archaeological artifacts. Preliminary results suggest the presence of high-energy streams with archaeological evidence found up to a maximum depth of about 6 meters. At the same time, high-resolution bathymetric surveys were carried out on the submerged sector of the archaeological sites, providing a detailed isobath contours that revealed a complex morphology of the lakebed. Two sediment cores about 5 m in depth were extracted from the lakebed offshore at 27 m water depth. Sedimentological analysis of lacustrine sediment revealed recurrent organic layers characterized by vegetal remains, consistent with the occurrence of remarkable lake level variations. Exploratory palynological analysis suggested a depositional hiatus in the uppermost portion of the cores. A suite of radiocarbon dates have been designed to define the chronological frame of the sedimentary sequences and to identify changes in timing and rate of sediment accumulation, both in the alluvial plain and the submerged lacustrine depositional environments.

Archaeological surveys and limited soundings have been carried out both in the fields around Mount Bisenzio and in the nowadays underwater region. The former provided evidence for a backdating of the earliest human presence in the area, the pace of the settlement evolution, as well as the extension of the residential area. The latter yielded contexts and stratigraphic sequences hinting at the lake level during the end of the archaic phase. Palynological and palaeobotanical investigations of in-situ archaeological samples and plant macroremains from domestic contexts allow to reconstruct the surrounding vegetational landscape, outlining some aspects of human activities related to the exploitation of natural resources at the site.

The Lower Havel River and Greater Donaumoos Regions: 'Failed' or 'successful' reclamation of floodplains and peatlands? – A comparative analysis

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The historical reconstruction of reclamation, colonisation and hydro-engineering in floodplains and peatlands is a key objective for improving our knowledge about human forcing on natural fluvial landscapes and environments (Werther et al. 2021).

The major aim of the new interdisciplinary project is a comparative assessment of these human interventions and corresponding ecological transitions towards two Fluvial Anthropospheres located in Central Europe. These are the Lower Havel River Region and the Greater Donaumoos Region. For the first time, we will reconstruct socio-ecological processes with a multi-methods approach from historical archaeology, geoscience and plant ecology. In addition, we will create through further data categorisations, transferable models and joint interpretations at intra- and interregional scales. We want to i) reconstruct human interventions on floodplains and peatlands during the medieval and pre-industrial modern periods, ii) reconstruct potential 'great transitions' and iii) validate the vulnerability of human intervention towards multidecadal climatic variability.

The presentation shows a first compilation of hydrological changes based on historical map records within both study regions and indicates fundamental changes of both natural river landscapes towards the development of Fluvial Anthropospheres.

Werther, L.; Mehler, N.; Schenk, G. J.; Zielhofer, C. (2021): On the Way to the Fluvial Anthroposphere - Current Limitations and Perspectives of Multidisciplinary Research. Water 13 (16), 2188, doi:10.3390/w13162188.

Interpreting the Holocene Deposits of the Niger River between Kotonkarfe and Idah in Northcentral Nigeria.

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Present-day deposits (sand bars and overbank muds) of the Niger River (Nigeria), to the north and south of Lokoja (confluence of the River Niger and River Benue), between Kotonkarfe in the north and Idah in the south were sampled and studied for their petrographic and palynological attributes to deduce the provenance and tectonic setting of the source area. Quartz, commonly rounded, is expectedly the dominant framework accounting for more than 70% of the mineral constituents with no felsic minerals in all sample points. The virtually complete absence of feldspar is attributable to the climatically-induced (warm and humid) intense chemical weathering in the crystalline basement parent rocks, mechanical breakdown as well as multiple sediment reworking during the long transport from the derivation localities. The heavy mineral suite contains some opaques, but the non-opaques are mainly the ultrastable trio – zircon, tourmaline and rutile (ZTR) species – exhibiting rounding and overgrowths. Palynological analysis of the overbank muds yielded fern spores, *Laevigatosporites* sp., *Retitricolporites irregularis* and *Zonocostites ramonae,* as well as fungal spores *Proxapertites cursu*s and the freshwater algae *Botryococcus braunii,* all of which indicate a transitional paleoclimatic phase of humid (alternating wet and dry) tropical climate. Thus, the mineral components of the fluvial channel sand bars, and the palynological faunal aspects extracted from the floodplain deposits, exhibit properties traceable to the long-distance transport along the Niger River drainage line heading from the Fouta Djallon in the Guinea Highlands under the prevalence of humid tropical climatic setting in the Holocene Epoch of the Quaternary.

What do megadunes look like and how were they formed? A story from the glacial lake-outburst floods in NE Poland at the end of the Weichselian glaciation

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Glacial lake-outburst floods are one of the geological processes that have contributed significantly to the evolution of the glacial landscape at the decline of the last glaciation. On the basis of geomorphological studies carried out in the proximal part of the Augustów outwash plain (Augustów sandur) and in the Rospuda outwash track (NE Poland), landforms typical for the glacial lake-outburst floods were identified and investigated. These landforms include mega-scale dunes (megadunes), classified here as two- and three-dimensional features according to their crest shapes. Two-dimensional (2-D) megadunes, occurring in the Augustów sandur, form three clusters. The first cluster is located south of Suwałki (sites Ateny 1-4 and Płociczno 1-4), the second lies south of Lake Wigry (sites Bryzgiel 1 and 2) and the third is located east of Augustów (Płaska 1 nad 2 sites). The 2-D megadunes on the Rospuda outwash track were identified in its central part and at the contact with the Augustów sandur (Topiłówka 2 and Augustów 1-2 sites, respectively), while 3-D megadunes were recognized in the distal part of the Rospuda outwash (Topiłówka site 1). Most of the analysed 2-D magadunes are characterized by the presence of crestal depressions. The main objective of the research was to identify the morphology and the architecture of sedimentary facies forming megadunes in north-eastern Poland in order to interpret their depositional environments. The observed sedimentary successions represent both immature and mature stages of megadunes development and indicate a multiphase evolution of these bedforms. The first phase corresponds to transitional conditions from sub- to supercritical flow regime, which was associated with the development of successive occurrences of humpback dunes, upper plane bed and bedforms of hydraulic jumps. During the second phase, the migration and overlapping of medium and large-scale sandy and sandy gravel bedforms occurred mainly under the condition of subcritical flow regime. In the third phase, as a result of the development of meta- and post-depositional normal, crestal depressions were formed.
This study was carried out as part of the scientific project financed by the National Science Centre, Poland, project no. 2018/31/B/ST10/00976 and Danish Council for Independent Research (FNU) grant DFF-7014-00156.

Reconstruct the paleoenvironmental changes in the arid area: Imprints in the sediment from Olgoy lake, Mongolia

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To assess the regional paleoenvironment, this study analyzed a 10.5 m sediment core retrieved from Olgoy lake (Olgoi Nuur) in the west central part of Mongolia. The sedimentary features are investigated as environmental proxies, including whole and mineral grain size, water, organic matter, carbonate, amorphous silica contents, and variations in elements analyzed by scanning X-ray fluorescence. The core was divided into six units based on lithology and analytical results: unit 1 with clayey sediments and brown silt, unit 2 is thoroughly dominated by silty layers, unit 3 depicted an abundance of sandy layers with brownish silt and gravel layers, unit 4 is dominated by sand and grey silt and intercalated gravel layers, unit 5 with brownish silt layers and unit 6 has alternations of mainly sand and gravel layers. The age model is given by OSL, IRSL, and Carbon-14 dating. Multivariate statistical analysis is applied to interpret long-term records. Factor 1 indicates in-lake activity and authigenic productivity. Factor 2 reveals detrital input /weathering/ terrigenous input, and Factor 3 implies the melting input from glacial and permafrost. MIS 2 and 3 stages were wet conditions in the Khangai mountains. At the same time, the Olgoy lake basin was humid. However, abrupt changes occurred via temperature increases accompanied by a dry climate during the Younger Dryas.

Three decades (1986-2015) of thermokarst lakes/ponds shrinkage on the northeastern Qinghai-Tibet Plateau

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Identifying changes in thermokarst lake dynamics has a significant impact on landscape-scale hydrology and carbon budgets in permafrost regions. Thermokarst lakes and ponds are abundant in the Headwater Area of the Yellow River (HAYR) on the northeastern Qinghai-Tibet Plateau (QTP). This study aims to quantify changes in thermokarst lakes and ponds for a 150 km^2 permafrost area in south-central HAYR as a representative area for the discontinuous permafrost zone on the QTP. Water bodies inventories were generated based on Landsat satellite images for the periods 1986, 2000, and 2015 using the supervised Maximum Likelihood Classification (MLC). MLC performed better than other supervised and unsupervised classifiers (k-means, Density Slicing) and machine learning algorithms (e.g., Random Forest, Support Vector Machines). Although the overall accuracy ranged from 96% to 97% and the Kappa coefficient from 0.87 to 0.91, manual editing of misclassifications was still required. The number of water bodies larger than 0.36 ha decreased from 1986 to 2015 by 40% (461 to 277), while the total surface area decreased by 25% (542 to 406 ha). The ponds category (smaller than 1 ha) recorded the most substantial change, as their number decreased by 44% and their water surface extent by 41%. Additionally, the surface extent of lakes larger than 10 ha declined by 20%. Most of the ponds did not disappear but shrank to sizes smaller than 0.36 ha. Moreover, many large lakes were partially drained, forming several remnant ponds too small to be mapped on this data. This shrinking pattern of lakes and ponds is consistent with the warming permafrost in the HAYR, which suggests intense permafrost degradation. Future work will focus on a better understanding of water-heat dynamics of thermokarst lakes and ponds in association with permafrost degradation at higher spatial resolution.

Insights on the events surrounding the final drainage of Lake Agassiz-Ojibway based on high-resolution analyses of the Lake Matagami varve series (Québec, Canada)

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The drainage of glacial Lake Agassiz-Ojibway in the North Atlantic at the end of the last deglaciation has long been held responsible for the 8.2 ka cooling event through a perturbation of the Atlantic Meridional Overturning Circulation. The impact of this freshwater forcing is still debated as the number and chronology of drainage events are poorly constrained in geological archives. Varve records provide an annual resolution on the lake's history, which spans over 2,000 years according to a composite sequence developed from varve sections across the Ojibway basin. However, part of the uncertainties about the succession and timing of late-stage events are due to the lack of resolution of a key varve sequence spanning the final stages of the lake history – the so-called Lake Matagami series. We sampled varve sequences from stratigraphic sections exposed along Lake Matagami (northwestern Québec, Canada), in addition to over 20 km of sub-bottom acoustic profiles to provide a high-resolution revision of the Matagami varve sequence and visualize the basin geometry. Varve sequences were analyzed using a CT scanner to document density variations and sediment structure. Varve couplets and thicknesses were counted and measured on these high-resolution images to correlate the sequence with the main Ojibway varve chronology template. Preliminary results show marked thickness variations indicating the influence of the fluctuating ice margin in sediment deposition. Upcoming grain size and X-ray fluorescence chemical analyses as well as the counts and measures should help correlate these sedimentological changes with nearby sections where drainage beds occur. Sub-bottom acoustic profiles show accumulations of more than 20 m of glaciolacustrine sediments, with occurrences of mass transport facies and erosional features consistent with active ice-margin dynamics prior to the final drainage of Lake Ojibway. Results from this study should improve the Ojibway varve series covering the final segment of the lake history and thereby contribute to refining the sequence of events preceding the final drainage of Lake Agassiz-Ojibway. Ultimately, refining the final deglaciation stages should help understand the role of the attendant meltwater discharges in the events that affected the North Atlantic climate in the early Holocene.

Constraining the contribution of Ungava-Labrador glacial lakes to early Holocene freshwater discharges: the case of Lake Cambrian in north-central Quebec (Canada)

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The retreat of the Laurentide ice sheet in northern Quebec and Labrador (Canada) led to the formation of several large ice-dammed lakes. These glacial lakes drained into the Labrador Sea where repeated meltwater discharges could have destabilized the North Atlantic Ocean conditions. However, assessing the impact of these freshwater inputs on the ocean circulation and climate is limited by the of lack constraints on the configuration, volume, and chronology of these lakes, as well as the position of the ice margin that controlled meltwater drainage pathways.

Here we studied the extensive sediment and landform records associated with glacial Lake Cambrian that occupied the Caniapiscau and Koksoak River valleys south of Ungava Bay in north-central-Quebec. Lake Cambrian was reconstructed through remote mapping of raised shorelines and deltas using high-resolution satellite images. Observations were validated through fieldwork, which allowed high-precision DGPS (± 1 m) elevation measurements of shorelines and deltas (45 sites) along a 170 km-long north-south transect. Preliminary results indicate that the lake experienced three well-defined levels at 180 m, 130 m, and 110 m. The occurrence of glaciolacustrine rhythmites suggests a relative long-lived stability of the lake basin. The extent of the lake will be reconstructed using a GIS model that corrects for the effects of post-glacial rebound and allows the calculation of realistic estimates of meltwater volumes. The chronology of the lake development will be constrained by the application of Terrestrial Cosmogenic Nuclide (10Be) dating to boulders of well-developed shorelines and deltas.

Together these results will constrain the development and evolution of Lake Cambrian and nearby glacial lakes during the last deglaciation and thereby reinforce paleogeographic reconstructions. Upcoming Be-10 ages will further place the meltwater discharges from the Ungava Bay region within the global deglaciation framework, which should lead to a better evaluation of the role of meltwater discharges in the early Holocene climate variations – an important contribution considering the recent increase in freshwater inputs coming from the melting of Greenland and other Arctic glaciers around the North Atlantic.

Keywords: deglaciation, glacial lake, quaternary mapping, cosmogenic dating

“Finis Ætatis Glacialis” – the drainage of the Central Jämtland Ice Lake and its connection to the Swedish Varve Chronology

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At the end of the 19th century, it was concluded that in the late stages of the deglaciation an extensive system of ice-dammed lakes, the Central Jämtland Ice Lake Complex, formed between the Scandinavian mountains in the west and the eastward retreating ice-sheet margin. Some years later, in the early 20th century, in his efforts to establish the varve-based “Swedish time scale” of the last deglaciation, Gerhard De Geer chose an exceptionally thick and coarse-grained varve in eastern Jämtland as the zero-year varve of his time scale, “Finis Ætatis Glacialis”; marking the end of the Ice Age and the boundary between the Finiglacial and the Postglacial subdivisions of the late Quaternary. De Geer believed this varve to stem from the opening of an eastern outlet and a catastrophic drainage of the Central Jämtland Ice Lake into the Baltic basin and, therefore, this zero-varve should represent the first definitive bipartition of the receding Scandinavian Ice Sheet.

However, the correlation between the zero-varve and a drainage of the Central Jämtland Ice Lake was only assumed and, at the time, no erosional features from the supposed enormous drainage had been found. In fact, since the middle of the 20th century, the very existence of the Central Jämtland Ice Lake has been challenged, and its palaeo-shorelines instead explained as formed in numerous marginal lakes within and around stagnant ice. Consequently, the draining of these lakes was believed to have been a more gradual process through a disintegrating dead ice-sheet.

About a century and a half after its first discovery, we now present geomorphological evidence in agreement with the original reconstruction of the Central Jämtland Ice Lake being a c. 3500 km^2 large and open lake, dammed by a coherent and actively retreating ice-margin. Most notably, we have found the “missing” extensive erosive features along with large sediment deposits relating to the catastrophic glacial lake outburst flood that followed when the damming ice margin broke in two. When this dam broke, the drainage was effectively reversed, from its western outlet across the present-day water divide to an eastern outlet and into the Baltic basin.

Microscale Approaches to Studying Glaciolacustrine Sediments – lessons from Palaeolake Riada, Central Ireland

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Proglacial, ice-contact lakes act as sediment sinks, providing a continuous record of meltwater and sediment output from ice sheets and glaciers. The resulting deposits are commonly rhythmically laminated and sometimes annually laminated (varves) useful for constructing high-resolution chronologies of glacier and meltwater inputs. These rhythmites are composed of multiple sub-millimetre laminations, that reflect variation in sediment and meltwater input paths and processes and can be used to reconstruct environmental change during the existence of the lake. Careful examination of these sedimentary structures, along with the temporal context provided by the seasonality of varves, allows detailed insight into sediment transport mechanisms and pathways. However, in order to describe and contextualise these laminations in full detail microscopy is needed.

Using cores retrieved from Palaeolake Riada, central Ireland, we explore three ways of examining sub-millimetre sedimentary structures - examination of cleaned sediment surfaces using low-resolution binocular microscopes, thin section analysis and scanning electron microscopy (SEM) of intact sample. We consider how useful each method is for identifying a range of features, some of which are useful for distinguishing varved sequences from other laminated sediments. These characteristics include textural characteristics, including grain shape and size and sediment fabric, the nature of contacts between laminations and internal grading of laminations, identification of intraclasts and dropstones, and a range of deformation structures including micro faults with millimetre-scale displacement, soft sediment deformation structures and possible bioturbation. Our results indicate that all three methods can provide useful information on primary and secondary sedimentary structures within these sediments and can assist palae-environmental reconstruction. We consider the implications of our results for sedimentation processes and environmental reconstruction for Palaeolake Riada. The lake sediments contain both varved and non-varved sediments that record the pattern of ice retreat, readvance, lake level lowering and final drainage of the palaeolake.

Reconstructing ice retreat of the south-eastern margin of the Laurentide Ice Sheet using proglacial lake sediments

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Establishing the behaviour and retreat of palaeo ice sheets is vital to better understand future global atmospheric and oceanic processes. The retreat of the Laurentide Ice Sheet (LIS) after the Last Glacial Maximum (LGM) led to a significant contribution of approximately 80 m to global sea-level rise, but the timing and impacts of this retreat are still not fully understood. Prior work has used moraines and till extents in the north-eastern US to spatially constrain the southern LIS LGM and post-LGM ice margins, but age discrepancies between cosmogenic nuclide ages (from moraine boulders) and ^{14}C ages (from lake sediments) have led to disagreements on the initial timing of deglaciation. This issue is further compounded by the inclusion of imprecise bulk ^{14}C ages.

To address this, the project aims to reconstruct ice lobe behaviour in north-east Pennsylvania (NEPA) using collated local ^{14}C ages and new high-resolution multi-proxy analysis of lake sediments. Previous works have focused solely on mapping NEPA glacial deposits, but very little research has been dedicated to constraining the timing of ice retreat within the region. This new data will therefore provide an important contribution to the overall LIS deglacial chronology.

Recent work at two NEPA lakes (Cranberry Pond and Nuangola Lake) show clear, gradual transitions from ice-proximal minerogenic to organic post-glacial sediments. New macrofossil AMS ^{14}C from the post-glacial clays constrain deglaciation to as early as 19.2 cal. ka BP; 3000 years older than the currently accepted AMS macrofossil ages obtained throughout the north-eastern US.

In this study, new sediment cores have been obtained from three NEPA lakes, transverse to ice margin retreat, to establish LIS retreat pattern and palaeoenvironmental change post-LGM. High-resolution physical (e.g. Grain Size Analysis, Dry Bulk Density, Magnetic Susceptibility), geochemical (e.g. X-Ray Florescence) and organic (e.g. Loss-on-Ignition) analyses have been used to trace changes in lake sediment characteristics. Chronological control is provided by ^{14}C dating of macrofossils at key stratigraphic boundaries. Importantly, these will be tied to the glacial geomorphological record using new cosmogenic nuclide ages from nearby moraine boulders to address potential environmental lag times.

Geomorphological and palaeogeographical significance of infilled lake basins: insights from the Cordillera Blanca, Peru

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The infilled lake basins represent common form in the complex high mountain landscape of the Cordillera Blanca, Peru. While recent case studies indicate that those areas influence sediment cascades and can help to buffer decreased discharge from shrinking glaciers during the dry season, a systematic inventory is lacking. In this work, I present an inventory of infilled lake basins of the Cordillera Blanca, analyze their morphometrical characteristics, types and occurrence patterns in relation to selected physical geographical variables. This inventory is further exploited to: (i) reconstruct past glacier extents considering large infilled lakes as indicators of LGM glacier limits; (ii) estimate the volume of trapped material and formulate the implications for sediment yield and mobility.

2000 years of small glacier activity recorded by a proglacial lake in South-East Tibet

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Mountain glacier ice cores provide detailed records of glacial evolution over the Tibetan Plateau. However, they reflect massive glacial systems, while small glaciers accounting for 50% of high-mountain Asia glaciers may have different dynamics, especially in the context of climate change. While the interpretation of stable isotope data in the monsoon domain is not straightforward, proglacial lake sediments may provide direct records of glacial activity in various settings through glacial induced erosion.

Here, we present a lacustrine archive recording 2000 years of glacial activity in SE Tibet. Lake Yun Zhu is a small (0.01 km²) proglacial lake in the Daxue range, eastern Hengduan mountains. Five cores ranging from 47 to 123 cm-long, were retrieved in 2021 with a gravity corer. The cores were dated using short-lived radionuclides, radiocarbon ages, and palaeomagnetic secular variations. Multiproxy analyses applied on these cores included XRF (continuous core scanning and discrete analyses), magnetic parameters, SEM observations of the sedimentary microfacies, grain size measurements, and hyperspectral data. Because the sediment is relatively homogeneous and poor in organic material, we used geochemical ratios and pigment analyses to reconstruct the evolution of detrital inputs and lake primary productivity. We show that clastic sediment derived from glacial erosion increases at the expense of organic production during cold periods. The observed peaks of enhanced erosion coincide with regional phases of glacier advances at 1320 ± 30 to 1410 ± 40 CE, 1490 ± 40 to 1590 ± 50 CE, and 1630 ± 50 to 1800 ± 40 CE, i.e., corresponding to the Little Ice Age period. We also indentified two older stages of enhanced erosion between 350 ± 30 and 510 ±20 CE, and between 1120 ± 30 and 1220 ± 30 CE.

Tracing Stone Tool Technology as Markers of Late Pleistocene Human Migrations in NE Asia and North America

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Recent review of human genetic markers and archaeological materials indicate the earliest occupations of North America have their roots in NE Asia during the late Pleistocene roughly 21,000-14,000 BP, however the details of localities and process of human movements are unclear. Some researchers (i.e. Buvit et al. 2021) suggest that late Pleistocene Paleo-Sakhalin-Hokkaido-Kuril (Paleo-SHK) peninsula and Honshu Japan may be the origin of founding populations into North America based on stone tool assemblage similarities coupled with periods of population out-movements from this region and timing of population in-movements into North America. To more clearly test whether stone tool technology can facilitate our understanding of these patterns, this paper is concerned with using stone tool technological markers as they are distributed over time and space during the late Pleistocene of NE Asia and North America. Utilizing cladistic analysis, key technological features of stone tool assemblages from several sites in NE Asia, including Japan and Siberia, occupied between roughly 21,000 to 14,000 ^{14}C BP are compared to those of early sites in North America occupied between roughly 16,500 and 12,000 ^{14}C BP. Comparisons focus on stone tool assemblage composition as well as specific technological markers and processes within each assemblage. These data are then set against geographical distribution of these attributes within sites and the radiocarbon record, thus providing geographic and chronological distribution of similarities and divergence in stone tool assemblages and technology over time and space. These data are then used to infer whether late Pleistocene Paleo-SHK and Honshu Japan contain foundational technological attributes of NE Asian lithic assemblages and subsequent population movements across NE Asia and North America.

New insights into subglacial processes in overdeepened settings revealed by swath bathymetry of young proglacial lakes

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The formation of subglacial overdeepenings is widely debated and essential for understanding glacial systems and their geomorphic processes. Knowledge of how landscapes were formed by glaciations is in particular important as receding glaciers currently uncover subglacial landscapes that are prone to a series of natural hazards. We present high-resolution bathymetric data of a proglacial lake in front of the Rhone Glacier (Swiss Alps) that started to form ~20 years ago and is not yet completely ice-free. These data were collected in two years (2015 and 2021) using a multibeam echosounder yielding a 1x1 m digital bathymetric grid allowing an unprecedented look into a freshly uncovered glacier bed in an overdeepened setting.

The bathymetry is characterized by a series of subaquatic moraines that exhibit various sedimentary features such as delta fans and subaquatic delta channels. The new data allow to accurately correlate the succession of these moraines with the glacier's retreat history as seen on aerial photos, providing critical understanding of when, where and how such subaquatic moraines form. Sub- and englacial conduits control the location of active and inactive lake-inflow channels. These conduits carry large amounts of sediments that rapidly infill the inherited subglacial landscape produced by the deglaciation. Moreover, comparing the two surveys from 2015 and 2021 enables us to quantify the accumulation and erosion processes in the central basin of the lake. The lake bed is further characterized by the backscatter-intensity map, which differentiates between fine- and coarse-grained sediment and bedrock, and by series of short gravity cores, allowing to identify channel activity evolution. Towards the glacier front, which still extends subaquatically into the lake, our high-resolution data visualizes how the submerged ice front is interacting with its proglacial lake. This highly dynamic frontal glacier setting is characterized by iceberg calving, as observed in September 2021, by fluctuating outflow conduits and by rapid sedimentation as particle-laden meltwaters and dumped glacial debris supply efficiently material continuously shaping and filling the lacustrine basin.

Mapping submerged beachrocks using low-altitude aerial photogrammetry-UAV on the northern coast of the Sea of Marmara, NW Turkey

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Low-altitude high-resolution aerial photographs allow for the reconstruction of geomorphological properties of shallow submerged beachrocks and the quantification of their topographic complexity. Beachrocks as a coastal deposits are largely used to estimate past sea-level positions and deformation rates in studies focusing on climate and tectonic processes at different temporal and spatial scales. In this study, we present submerged beachrocks relative paleo sea-level indicators found on the nearshore coastal area of Tekirdag city (Altinova), the northern Sea of Marmara. However, our knowledge of the submerged beachrocks in the Sea of Marmara coasts is limited and scarce. The Tekirdag-Altinova coastal area is also located in the tectonically active western Marmara Region. This tectonic activity is controlled by the North Anatolian Fault Zone which played a crucial role in the coastline evolution at different periods of the region.

Recent studies of submerged beachrocks using UAV data have demonstrated that these deposits can be readily isolated from other coastal deposits in the coastal area. Thus, the submerged beachrocks were identified at a depth 2 m below the present sea level with a ~5 km coastal extend, by using a combination of high-resolution aerial photos and morphological analysis techniques in this region. It was used specifically to generate a dense point cloud and then a high-resolution bathymetry of these beachrocks by correcting the effect of water on light refraction. Hereby, the Structure-from-Motion photogrammetry technique was exploited for low-cost and effective UAV-derived imagery to achieve the monitoring of these beachrocks.

Then, to accomplish the objectives a high-resolution bathymetry (5 cm) was analyzed using Geographic Information Systems and Terrace M application. This application allows estimating the shoreline angle and its associated error using high-resolution bathymetry. Then, shoreline angles, a geomorphic feature correlated with the high-stand position of past sea levels, were mapped by analyzing swath profiles perpendicular to the isobaths. In summary, most of the submerged beachrocks with their shoreline angles between approximately -0.3m and -1.1m. The preliminary results gave us novel routines to map the elevation and spatial distribution of beachrocks and to estimate reliable uplift rates in the nearshore area of the study region.

First pollen record from the Late Holocene forest environment in the Lesser Caucasus

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Pollen-based vegetation change has been inferred from sediments in Kalavan Red Lake. This small lake is placed in the beech-oak-hornbeam forest, about three kilometres away from archaeological remains. It has the potential to document the Holocene forest history and climate and human impacts on the Lesser Caucasus, West of the Caspian Sea. However, this lake happens to be formed by a large landslide.

Pollen and XRF analysis are provided over the last 3800 years. The basal age of the Kalavan sediment approximates the landslide age. This created a not vegetated slope including the lake catchment. Erosion and sedimentation processes brought coarse and heavy minerogenic elements, declining with the catchment revegetation by tall-grassland. This shift in the sedimentation continues, suggesting less erosion in the catchment when an admixture of *Quercus* and grasslands settled. Starting from 2000 cal. BP, arboreal pollen increases successively thanks to the step afforestation of *Quercus*, *Carpinus orientalis* and *Fagus*.

The comparison with available pollen reconstruction illustrates the uniqueness of the vegetation dynamic recorded at Kalavan. However, the duration of this succession is also questionable. An intermediate hypothesis is proposed: the Kalavan's dynamic is first initiated by the landslide with the tall-grass development, then paced by the regional vegetation dynamic.

Linking vegetation history and erosion with regional climate and archaeological data helps to evidence short-term climate change and human impact on this branch of the Silk Road. Antique arid phase (2000-1600 cal. BP), the Medieval Warm Period and Little Ice Age affect the vegetation, while demography variations during the Medieval period and Modern Age are shown by habitation and pastoral activity.

Evidence for an Illinoian (MIS 6) aged 3,500 km2 proglacial lake in the Midwestern United States

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New surficial geology mapping efforts have revealed the presence of Glacial Lake Prior, a proglacial lake which was formed by an Illinoian Episode (MIS 6) ice lobe. The flow path of the ice was southwest then westward out of the Great Lakes region and dammed the Wapsipinicon, Cedar, Iowa, and Skunk rivers in Iowa. Water well records in the area contain fine-grained sediment, interpreted to be lacustrine in origin, and coarse-grained outwash buried by Illinoian (MIS 6) till. There is also a distinctive upland morphology caused by a repeated "fill-and-spill" process. As ice dammed rivers, valleys at higher elevations filled with water until they would overflow into adjacent basins via the lowest path, i.e., pre-existing tributaries. The modern upland surface contains forms of these overflow channels, and they have a similar slope dipping to the south.

Glacial Lake Prior offers a unique perspective into the processes and interactions between continental ice lobes and pre-existing drainage networks. Specifically, ice flowing against the established drainage pattern. In addition, the valleys buried by the ice advance do not match the geometry of the modern Mississippi River Valley. This, combined with the fill-and-spill geometry, support the idea that major river diversions are primarily controlled by ice proximity rather than long-term isostatic processes. Future work will constrain the timing of Lake Prior's development and its interaction with the Illinois Lobe and older glacial advances.

Human-animal interaction in the Harappan Civilisation: regional distribution of domesticated animals and an evaluation of current research practices

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Archaeozoological studies of Harappan sites have become increasingly common in the last few decades, and a general top-down understanding of animal utilization within this civilization now exists. However, our knowledge about the variation in regional human-animal interactions is extremely limited, particularly if regional geographical, climatic and socio-political differences impacted how domesticated animals were exploited. Furthermore, most Harappan faunal analyses are site-specific and not uniform across the pan-Indus region. Not only are the site-specific data sparsely distributed across the civilization, but the collection of samples, analysis and data presentation methodologies employed by researchers need to be standardized. This lack of standardizations adds additional obstacles in translating site-specific faunal information to larger geographical contexts. Using already published data, this paper aims to reconstruct the region-specific distribution of domesticated animals within the Harappan Civilisation and, in this process, evaluates issues related to method, data standardization and publication within the field of Harappan archaeozoology. Using an array of statistical measures, this paper will discuss legacy data to estimate if the exploitation of domesticated animals varied across regions or if they were standardized, and what the extent of this standardization was within the civilisation. By factoring in differences in methodologies applied to interpret zoo-archaeological results from different sites, this paper will also discuss the sources of bias and the possible existence of inter-analyst variation. Recognition of these analytical conundrums has broader implications for developing a bottom-up understanding of human-animal-environment interaction within the Harappan civilisation. Furthermore, the geographic distribution of domestication practices within the Harappan Civilisation will help reconstruct the regional cultural response to geographical and climatic variation and how animal herding and exploitation practices may have varied spatially and temporally. As the first great civilization in South Asia, knowledge of Harappan adaptations to the environment is a step towards understanding the larger sociocultural evolution of humans in this part of the world.

Sclerochronology of pectinids from the warm Mediterranean Pliocene: what can we learn about species response to future climate change?

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Sclerochronology investigates the geochemical composition of bivalve shells and gives insights on climate conditions archived during the lifetime of an organism and its adaptation to them. Growth increments represent interval of times in which the organism produces its shell, and can inform on environmental conditions during growth, and growth lines identify periods of growth cessation, which can be caused either by physiological processes (e.g., spawning) or abiotic factors, typically temperature.

Here we analyse the relationship between micro-growth increments and stable-isotopes ($\delta^{13}C$, $\delta^{18}O$) of two stenohaline Pectinidae, *Gigantopecten latissimus* and *Pecten jacobaeus*, from Zanclean (Early Pliocene) deposits (Tuscany, central Italy). *G. latissimus*, with large (length > 20 cm) and heavy shells, got extinct around 3.0 Ma ago, when Mediterranean Sea surface temperatures shifted from subtropical to temperate at the intensification of the Northern Hemisphere glaciation. *P. jacobaeus*, survived to Plio-Pleistocene climate cooling and is the largest scallop inhabiting the Mediterranean Sea today (length up to 15 cm). Aim of the study was to characterize the growth patterns of the two species and to investigate whether different life strategies might have controlled species extinction or survival.

In *G. latissimus*, strong correlation between growth patterns and $\delta^{18}O$ values ($p < 0.001$) clearly indicates high growth rates during the colder months (higher $\delta^{18}O$) and slower rates during warm periods, with summer cessation. This behaviour resembles that of large modern subtropical scallops, like *Nodopecten subnodosus*, in which spawning occurs only once per year, at the end of the warm season. Given this specialized physiological adaptation, we hypothesize that a drastic decrease in summer temperature after 3.0 Ma, hampered the reproduction potential of *G. latissimus* contributing to its extinction.

In *P. jacobaeus,* although we observe a tendency of precipitating the shells during colder intervals, the correlation between growth patterns and $\delta^{18}O$ values is not significant, suggesting a more variable life strategy for this species. Studies on modern specimens confirm this interpretation, showing that *P. jacobaeus* displays growth summer cessation but also has multiple spawning seasons through the year, making it more adaptable to a changing climate.

The stratigraphy and sedimentology of the Roman-Byzantine El-Araj archaeological site at the northern coast of the Sea of Galilee, NE Israel

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The archeological site of El Araj (Bet Habek) is located on a large delta deposited by the Jordan River and three other central Golan Heights streams. It is situated on the edge of a pronounced shoreline break, where modern lake level reaches a maximum height of 208.8 m below sea level at the contact with the delta front. The Roman-Byzantine archeological excavation of El-Araj is 3.5 m deep located over natural fluvial basalt gravel and coarse sand layers with the absence of the molluscs typical for the lacustrine deposits of the Sea of Galilee, indicating that the site was settled over a dry natural alluvial fan, while the lake shoreline was further to the south. This suggests that the lake level was lower than 211.5 m b.s.l. However, natural fluvial layers up to 0.4 m thick were found covering the Roman archaeological layer at 211m b.s.l. under the overlying Byzantine layer at 210.5 m b.s.l.

The general stratigraphy and sedimentology of the site suggest alternating lake sediments with coarse fluvial sediments transported during large floods. The coarse texture of the natural layers resembles the texture of some of the layers exposed at the nearby bank of the Meshushim stream supporting the fluvial origin of the sediments rather than the finer lake layers. The trace of the nearby N-S Jordan fault – a segment of the Dead Sea Transform (DST), located about 600 meters east of the site, does not show any local evidence of surface rupture neither sedimentological evidence for liquefaction at the site. Nevertheless, some subsidence along the fault may have formed an accommodation space for the fluvial deposition.

Our conclusion is that the Roman archaeological layer was buried by fluvial sediments from floods probably originated from the Meshushim stream.

Poster - sessions 10, 38, 56, 78, 95, 107, 108, 109, 115, 121, 180, 182, 184, 187

The 3D Pollen Project: super-resolution scanning a representative sample of the world's pollen diversity in two and three dimensions

Dr. Oliver Wilson [1]***, Prof. Robert Marchant*** [1]

1. *University of York*

Pollen is fundamental to the functioning of the natural world, and to the sciences which research it. This extends far beyond palaeoecology. The flow of beautifully patterned pollen grains underpins plant reproduction and evolution, ecosystem function and productivity – and ultimately human health. Pollen grains, preserved in rocks and sediments by immensely tough outer shells, reveal the development, adaptation and decline of species and ecosystems from geological to human timescales. And for hundreds of millions of people worldwide, pollen simply gets up their nose (perhaps 30% of the global population is allergic).

Engaging non-specialists with pollen-related research can be challenging, though – not least because pollen is microscopic. 3D scanning and printing can produce morphologically accurate, larger-than-life, tactile models of pollen grains, and has allowed audiences to interact with pollen in new ways – to hold these microscopic marvels in their hands and bring close the worlds of pollen and related research. However, to date, only a small and biased subset of the world's pollen diversity has been made available for these purposes.

The 3D Pollen Project aims to scan and share 2D and 3D data on a representative sample of the world's pollen types, for use in outreach, education and research. New technological approaches, combined with superresolution scanning and traditional microscopy, allow for the high-throughput digitisation of existing pollen reference collections, producing data with SEM/TEM-like resolution without requiring additional processing. This poster sets out how we are applying these methods to a large and (ecologically, geographically, morphologically and phylogenetically) representative sample of the world's pollen diversity – and explains how you can help.

PalaeoScope: an augmented reality app for visually telling stories about the past

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The Acropolis of Athens is one of the most visited landmarks of Greece. Located on the top of a hill, at the center of Attica basin, it offers an excellent view of Athens. Since most visitors spend a significant amount of time taking pictures of the city with their phones, it makes only sense to create an app for telling stories about the city and its environment. We therefore developed an augmented reality app that turns phones into a tool for visually describing the landforms, vegetation, and animals of the past. The phones will use their video-see-through systems to overlay visuals onto the live environment. The early Pleistocene, early Holocene and the historical periods play key roles in our reconstructions. The recreation of the past has required our scientific team to push beyond typical questions and data. For example, the team had to make decisions about the spatial distribution of flora during the Pleistocene and early Holocene. Such data are few for Attica basin, thus our team had to additionally rely on palaeobotanical data from other localities with compatible geomorphological and climatological attributes. Literary sources and landscape depictions were also used for the reconstruction of vegetation in historical periods. The early Pleistocene faunas are well represented in Attica. Two fossil localities, Tourkovounia and Psychiko, have yield fossil vertebrates ranging from MN16 till MNQ19. Nevertheless, they consist mostly of small vertebrates. We therefore used data from other Greek localities for recreating a realistic Pleistocene megafauna. Palaeozoological data for the early Holocene were taken from Vraona (East Attica), which yield a significant number of large-mammal fossils. Our app aims to help the public engage with the past. For example, by contrasting the present human-shaped landscape with that of the early Holocene, the visitors can realize that the rivers of Attica are forced to flow in sewers bellow major avenues, that the present vegetation in Attika is depleted and that the megafauna is absent. This research was co-financed by the European Regional Development Fund of EU and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, call Research-Create-Innovate (Project: PalaeoScope T2EDK-03781).

Climate change – the boardgame: a free educational resource to discuss paleoclimate, evolution and conservation

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Climatic variations through time are one of the key drivers of evolutionary dynamics in animal species, leading to changes in distribution, migration, adaptation, or extinction. While specialists are aware of how the different factors involved interact in complex and variable ways, most often the general public fails to grasp the overall complexity of the picture.

We decided to increase awareness about this topic by creating “Climate Change – the board game” (https://michelaleonardi.netsons.org/climate-change-board-game/) inspired on our research on how climatic changes affect animal species over long timescales.

In the game, each player is a species, living in a world where the climate may change without warning. Each species has a given genome with associated traits that, through mutations, allow it to adapt to different environments. Whenever the climate changes, the environment follows and the species must react by migrating or adapting, or it goes extinct.

This board game explores in a rigorous but simple way complex scientific concepts such as adaptation, evolution, and extinction. There is also the opportunity to explore the effects of the current human-induced climate changes with respect to natural ones.

The game is available in four different languages (English, Italian, Portuguese and Turkish) and can be played for free either in person by downloading the materials or online through the dedicated website.

Challenges and opportunities in communicating interdisciplinary paleoscience

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In current times of environmental crisis it is crucial to effectively communicate scientific results. Scientists are often confronted with the question of how to communicating their research outcomes to different audiences and in different contexts. In November 2022, during the Past Socio- Environmental system workshop in La Serena, Chile, 26 Early Career Researchers (ECRs) from different paleoscientific backgrounds gathered to discuss the overarching themes of past climate-environment-cultural changes. During focus sessions participants worked on three main questions that summarized 150 questions posed by the ECR community, which revolved around types of proxies and archives, semantic barriers, and analytical frameworks in past socio-environmental systems. Challenges and opportunities of communicating interdisciplinary emerged as a transversal theme encompassing the summary questions and was further developed as a pivotal point of discussion. Challenges and opportunities were divided in three main topics 1) Research, 2) Funding 3) Outreach. For each topic the main actors were identified and challenges and opportunities further outlined. An *Octopus* was used as a graphical visualization where tentacles represented all the different aspects an ECR has to consider when it comes to communicating science. The message being that ECRs do not have to act as an octopus trying to juggle between different ways of conveying information but rather focus on preferred aspects as an opportunity, among others, to increase their visibility, develop further skills, and increase networking opportunities.

Communicating Quaternary science to community collaborators in Timor-Leste

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Quaternary science is a unique form of storytelling that emphasises past changes as a means of understanding the world. This emphasis on the past means that Quaternary science could have much to share with Indigenous cultures with long oral histories and deep storytelling traditions. But there are significant barriers to this kind of dialogue, in part due to the lack of a common language and the mistrust engendered by colonisation. How can we explain Quaternary science in ways that resonate with local communities? How can we create possibilities for telling stories together about the past that are inclusive, scientific and culturally relevant? In this presentation, we describe a children's book developed by our joint Australian-Timorese team: "How to Understand Past Climate Changes?" Through the medium of watercolour illustrations, we communicate Quaternary research questions, methods and outcomes in ways that diverse audiences can quickly and easily grasp. The book is written in three languages as a teaching resource for Timorese schools and it will be made available through Creative Commons licensing so communities can make it their own. Communicating science in this way is time-consuming and overlooked in current research metrics, but can open pathways to stronger connections with communities and places, as well as facilitate a deeper understanding of the Quaternary through the sharing of different knowledge systems.

A timeline for the history of Quaternary studies in Italy from Arduino to the nineteen-seventies

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We present a timeline stepping the development of Quaternary sciences in Italy, starting by the origin of the Quaternary concept, which was given by Giovanni Arduino. We focus on historical milestones achieved until the onset of contemporaneity.

The marine sediments of Southern Italy stimulated stratigraphic research since Lyell introduced the "Newer Pliocene" (1831), then renamed Pleistocene. Several marine stages were defined in Italy - Sicilian, Calabrian, Tyrrhenian, Milazzian and other later on. The 18th IGC in London started the debate on the Plio-Pleistocene boundary, to be placed "at the horizon of the first indication of climatic deterioration in the Italian Neogene succession" on the base of changes in marine faunas.

The post-Tertiary continental deposits were mapped as "alluvial" and "diluvial terraines" until 1870. Glacigenic deposits were recognized at the foot of the Western Alps (1850), and Central-Eastern Alps (1861). Around 1890, researchers started to distinguish more than one glaciation and first recognized glaciers in the Apennines. Since 1909, the four-glaciation scheme was generally adopted.

Yet in the Renaissance, Quaternary mammals remains were collected from the Upper Valdarno. Around 1900, the knowledge of the Pleistocene mammal fossil record in continental Italy greatly improved and new endemic species were discovered in Sicily and Sardinia. In 1865 the Villafranchian Stage was proposed for the fluvial and lacustrine sequence of Villafranca d'Asti (Piedmont). The mammalian faunal assemblage of Villafranca led successively to the definition of the "Villafranchian European Land Mammal Age".

The Quaternary paleobotanical identity was pointed (1833), as "characterized by animal and plant species similar to modern living ones at the same site". Plant macrofossils species were then classified by the Linnean system. In 1896 the aliquot of extinct and eradicated plant relicts in N-Italy was stepped through the Pliocene, interglacial and the postglacial periods. Evidence from excavating peats stimulated a stratigraphic organization of the macrofossil record. In 1931-32, the introduction of palynology in Italy promoted the application of micro-botanical stratigraphy to vegetation history and to plant-climate-human interactions.

Lastly, we outline the beginnings of paleoanthropology and the noteworthy Paleolithic human remains discovered in Italy.

If lakes could tell stories...: an illustrated children's book about Palaeolimnology

Dr. Celia Martin-Puertas [1]

1. Royal Holloway, University of London

Written by Celia Martin-Puertas
Illustrated by Samuel Torres
Scientific learning in early childhood is important for future scientific understanding but also to build important skills and attitude for thinking. Literacy has a transformative power and may be an engaging learning resource at home but also for classrooms. The number of scientific books for children is increasing in the last years and they cover a wide range of disciplines, although Quaternary Sciences is still underrepresented.

"If lakes could tell stories" is an illustrated children's book about palaeolimnology, which takes children on a journey into lake sediments and time travel. The book describes the basic steps to study the evolution of a lake, from lake coring to sampling, environmental interpretation of proxies and developing of a chronology. The book offers children the opportunity to explore their world and promotes palaeo and Quaternary literacy as to support early years teaching and learning.

PollenScape: a tactile teaching and engagement tool for visualising landscapes of the past.

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When palaeoecologists (palynologists) extract pollen from their sediment cores and peer down the microscope, they reconstruct what was growing in the landscape back through time. At least this is what the specialists sees. It is much harder for the public, school students and even our undergraduates to make this cognitive leap. The PollenScape project is an educational tool that enables students and the broader community to overcome this challenge and connect more meaningfully with our research.

Studies have shown that hand-held 3D models reduce many of the obstacles associated with the study of complex structures and data, providing students with a more enjoyable learning experience while, at the same time, developing a learning environment that encourages deeper engagement. To do this effectively we need to bridge differences in knowledge, experience, and backgrounds, to communicate not just our findings but the research process itself.

PollenScape is all about linking what we see under the microscope with a 3D hands-on reconstruction of landscape and builds on our existing contributions to public and research good with the creation of a unique communication tool, making accessible a complex discipline that many people find beautiful and fascinating.

Science communication for community engagement in Australian Quaternary Science.

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Engaging with local communities, schools, and other stakeholders is an increasingly crucial aspect of Quaternary Science research globally. Engagement comes in many forms, including ongoing discussions with all stakeholder groups surrounding permission and consent, as well as the active participation of communities in the processes of knowledge production. For successful engagement and a high level of participation, long-term partnerships, knowledge sharing, and informed consent need to be established for all groups involved. This includes effective communication of the goals, techniques, and outcomes of the research. However, this is often complex, such as when working in remote regions where communication with groups is limited, or in communities where different primary languages may reduce understanding. Science communication tools provide an opportunity to effectively communicate this information. Tools such as brochures, infographics, flyers, and websites can be used to visualise knowledge and methods with diagrams, maps, and photographs for local communities.

In Australia this is of particular importance where all research is occurring on unceded Indigenous lands and informed consent to undertake research is important, especially for important cultural and spiritual sites. The ARC Centre of Excellence for Australian Biodiversity and Heritage (CABAH) is working to develop a series of resources for science communication and engagement, including brochures, infographics, website links, and videos. CABAHs mission statement is to conduct culturally inclusive research and collaborate with local Indigenous communities. These resources aim to explain what, why, and how scientists perform work on Country, targeted at local communities and other stakeholders. This will help reduce the confusion and miscommunications that often surround this work to build informed consent, as well as encourage the participation of communities in research. Visual content explaining different aspects of the research undertaken by CABAH is essential to explain techniques and build informed consent for all groups. Many of these projects also aim to build knowledge and skillsets for communities by guiding groups through these activities via guides and videos on websites. Ultimately, both series aim to visualise science to create informed consent, build long-term partnerships, and encourage active participation of local Indigenous communities in Quaternary Science research in Australia.

Painted Stories of Norway Spruce Migratiion in Scandinavia

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How we as scientists communicate paleo-genetic-research can be complicated. Yet many people would be fascinated to learn more about ancient DNA studies: how DNA is carefully extracted and transformed to piece together Earth's relatively recent biological past. As this technique evolves, so does its capability to answer important questions about evolution, phylogeography and origin of species. Collaboration amongst natural science disciplines is a necessity to addressing the myriad of questions about Earth's history. Additionally, collaborating across other disciplines outside of the sciences can help to expose this research to broader audiences. Paleo-genetic-research has the power to capture human imagination by painting a picture of our past as a species. Therefore, utilizing that potential is a keyway to gain interest in and support of this type of research and art can be used to help illustrate graphical results, depict laboratory processes, or highlight the stories about the past we are uncovering. One method to doing so is to create artwork with effective visual narratives of Quaternary studies. In this presentation I will show results from our recent collaboration with artist and climate change scientist Jill Pelto who created five paintings depicting research and laboratory processes of a recent work done in Scandinavia using ancient DNA extracted from lake sediments.

InSAR surface deformation, geological structure and fault model of the 2019 Mirpur earthquake.

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The Himalayan Mountain belt is seismically very active due to the continued convergence between the Indian and Eurasian plates. The current active deformation is largely concentrated around the Main Front Thrust (MFT), where several moderate to high-magnitude earthquakes occur. In this work, we map the coseismic surface displacement of the 24 September 2019 Mirpur earthquake (M_W ~ 5.4) using ascending and descending pass LiCSAR data. The coseismic displacement maps indicate clear deformation lobes corresponding to uplift (+) and subsidence (-). The coseismic displacement ranges from +9.2 cm to -5.6 cm and +6.3 cm to -7.0 cm in ascending and descending passes, respectively. Visual inspection of the displacement maps did not reveal any evidence of a surface rupture. The two-lobe displacement pattern and the absence of surface rupture suggest the blind nature of the causative thrust fault. Spatially the uplift and subsidence areas correspond to the Mangla Samwal Anticline (MSA). The deformation extents in ascending and descending passes are marginally shifted relative to each other indicating minor horizontal motion due to the earthquake in addition to the predominant vertical motion.

The inversion of coseismic deformation was carried out using Steepest Descent Method (SDM). We also considered a structure model developed from regional geological information, remotely sensed imagery and published literature while inverting. It considered one, three, four, and six fault panels with varying dips. The length of the MSA is maintained at 7 km. The width, depth, and dip of the six panels are assumed according to the structure model. The six-segment model performed better than the other models indicating a data-model correlation of 0.82 and 0.94 with mean residual of 1.8 cm and 0.7 cm in ascending and descending passes, respectively. The inversion results suggest that the earthquake occurred at a depth of 6.1 km on a fault striking ~ 290°. The resultant maximum slip is 0.85 m, and the derived moment magnitude is Mw 5.8. In conclusion, it is inferred that geological considerations significantly improved the assessment of surface deformation and allowed a more consistent fault model.

Reassessing the oldest archaeological evidence of Colombia

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Colombia is the gateway to South America, the first territory to be settled by the early humans moving from Central to South America. Despite its crucial role in the international debate on the first peopling of South America, the prehistory of Colombia is an under-researched field and the earliest human evidence remains controversial.

The scarcity and fragmentary nature of the earliest archaeological record, together with the presence of critical elements related to several sites, prevent a full and detailed comprehension of chronology, routes of dispersion and technology of the earliest hunter-gatherers of Colombia. Considering the almost absolute absence of anthropological remains for the most ancient period in Colombia, the study of lithic technology is an issue of primary importance because it is a clue to ancient dispersals, subsistence and adaptation strategies.

The early human settlement of Colombia is characterised by a widespread interregional technological and typological diversity in lithic assemblages, distinctive contemporaneous regional features and patterns, whose origins and interactions are still unclear. According to the available evidence, the early peopling of Colombia occurred during the final Late Pleistocene/Early Holocene (ca. 12,500 – 9,000 BP). More precisely, the oldest sites of Colombia (final Late Pleistocene) are located on the Andean highlands, precisely in the Sabana de Bogotá (Eastern Cordillera, ca. 2,600 m.a.s.l).

In this area the most important sites of the territory were discovered by the end of the 1960s/beginning of the 1980s: El Abra and Tibitó represent the reference sites not only for the prehistory of Colombia but also abroad, traditionally mentioned in any synthesis on the early human peopling of South America. Here we present a critical overview of the oldest archaeological evidence recovered in this area, the result of a multi-year revision work. Our results reveal several discrepancies and critical elements contained in previous studies, with repercussions, not only on the interpretation of the lithic industries but also on the chronology of the sites.

Techno-economic approach to early lithic industries of Fuego-Patagonia: dynamic interactions among culture, society and the environment at Finis Terrae (50º-56º South Latitude)

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The techno-economic approach used to study the early lithic materials from Fell cave and Cueva del Medio (c. 13.000 cal BP), in comparison with Holocene industries from Punta Santa Ana 1, Marazzi 1, Cabo Monmouth 20, Pizzulic 2 and others representing the oldest peopling of the western channels and archipelagos of Fuego-Patagonia are discussed. Three main axes are assessed: transport and interactions related to non-local raw materials; second, elaborated core reduction methods and débitage with predetermination (for example Levallois, bifacial shapping, blade and blade tendency reductions) as the action modes that can be related to complex processes of knowledge sharing and transmission; and functional analysis related to *chaine operatoires* and tool kit behaviour managements.

The comparison of spatial and chronological information related to these main axes of discussion allow us to move from general trends of macro-regional scale that display the existence of shared conceptions, as in an integrated, transmitted and generalized knowledge corpus for Fuego-Patagonia, to very specific understanding of tool kit strategies deployed at particular archaeological sites. Still a large range of techno-economic strategies are observed and better understood within multiple scales and degrees of interaction among human groups and paleoenvironments.

The results have direct rapport with the key role of the early marine nomads since c. 7000 cal BP and dynamics related to biogeographic barrier notions relative to the Strait of Magellan, for example. Thus, the existence of a common cultural background that transcends the terrestrial-maritime dichotomy and in-between group division (cfr. ethnic) is worthy of remark and discussion, as other sources of information as genetic, diet, bioanthropological, etc. The geographic and time distributions of lithic industries can be approached as measurable data changes regarding interaction intensity and adaptation, and general dynamic co-evolution among cultures, societies, and the environment.

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Early maritime peopling of the Pacific tundra and the first archaeological records from Brecknock Peninsula, Tierra del Fuego (54ºS/72ºW)

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The maritime peopling of Fuego-Patagonia is framed by scenarios of significant change related to global eustatic processes that shaped the landscapes/seascapes and combined with regional dynamics of isostatic rebound, and tectonics, transformed this space into fully maritime environments c. 9,500 cal BP. This suggests that the available chronology for early marine human settlement may be biased by the effects of marine incursion, associated with the loss of emerged surfaces and potential archaeological evidence due to the erosive action of the sea and/or submerged landscapes, key issue for the discussion of initial peopling of South America. On the other hand, we propose that there are other types of biases associated with conceptual frameworks and interpretations that have ignored data that precedes the archaeological assemblages defined as the early expression of marine adaptations in this region. We consider two relevant axes of research: the first is anchored in the expansion of the geographical scale of survey, incorporating a broad insular area. Second, we propose the exploration of sectors that are now submerged, based on paleoenvironmental and geomorphological reconstructions that nourish and guide archaeological survey.

The first results of this research for early evidence of maritime peopling at the archaeological site Brecknock 1 are presented. Surveys at the southwestern extreme of the Fuegian archipelago, an area associated with hyperhumid Magellanic tundra environment, have rendered conditions of low to null archaeological visibility and the record of the earliest human occupations with c. 7,000 cal BP. The evidence is consistent with the idea of a wide range of geographic dispersion for marine hunter-gatherer populations with navigation media. The findings suggest circuits of long-distance human mobility, supported by elements such as obsidian lithics. Also, results show that preservation conditions of organic elements, except for periostracum and charcoal, have obliterated most of the archaeological record. In other words, it is a search for evidence with little or no preservation of shells, bones and hard animal materials.This presentation is funded by grants: ANID/BASAL FB210018, FONDECYT 1211976.

Can we use geochemical signals to link tsunami deposits and seismo-turbidites in a coastal lake system? First results from Lakes Cucao and Huillinco (northern Chilean Patagonia)

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A main challenge in subduction zone paleoseismology is the evaluation of event synchronicity across sites. This is due to age uncertainties of paleo-tsunami, paleo-rupture and paleo-shaking events which are typically in the order of decades/centuries. Therefore, it is difficult to robustly reconstruct the along-strike rupture length and downdip location of megathrust ruptures.

Here we study a coastal lake system on Chiloé Island (northern Chilean Patagonia) and test whether we can stratigraphically link (published) tsunami deposits in coastal Lake Cucao with a new seismo-turbidite record from the connected lake Huillinco. Lake Cucao is separated by a ~1.1 km wide barrier from the ocean and holds a 4.2 kyr record of past tsunamis in the form of sandy clastic deposits within organic-rich mud. Tsunami inundation is facilitated by a river channel connection, which at present is an active tidal channel due to coseismic subsidence of the giant 1960 earthquake (M_W 9.5). However, its past role is unclear. Lake Huillinco is located 2 km farther inland of and is deeper (47 m vs 25 m) than Cucao, which makes it ideal for recording turbidites induced by seismic shaking. The lakes share their lake level and are connected by a narrow and over-deepened river channel.

For correlating the sedimentary records, we trace geochemical signals in the organic-rich background sediments by using high-resolution XRF scanning, TOC, C/N and C/S. XRF scanning data is processed by PCA and cluster analysis in the center-log ratio space. Some of the inferred geochemical signals are interpreted as the result of marine inundations by tsunamis and/or following coseismic subsidence, leading to a trapped saline water body in Huillinco. This leads to a strong water column stratification and anoxic bottom water conditions, allowing varve formation for a few decades following the events. To better understand the geochemical signature in the sediments, we also studied the transient nature of the post-1960 saline water body by comparing water-column data of a study in 1997 and our survey in 2022. Our approach bears the potential of directly linking past evidence of seismic shaking, tsunami and maybe coastal elevation changes within a single chemo-stratigraphic framework.

A continued long history of earthquakes and Chilean lakes

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In recent years, a wealth of lacustrine paleoseismic studies has emerged around the world, providing often long and highly-sensitive shaking records. These are particularly powerful in regions where more traditional paleoseismic techniques such as trenching or reconstructions of land-level changes are not feasible, or cannot completely and reliably grasp the manifold of seismic hazards that exist in these settings. In this respect, the south-central Chilean subduction zone has been extensively studied, resulting in the identification of sedimentary shaking imprints in no less than 20 lakes and fjords. Correlation of these records and integration with other coastal paleoseismic and -tsunami archives provided qualitative estimates of the recurrence mode for different types of rupture sources, notably for megathrust earthquakes. Full-segment ruptures, like the M_W 9.5 1960 Valdivia earthquake, occurred repeatedly in the last two millennia. Additionally, numerous partial ruptures and a rupture cascade have been identified alongside a notable seismic quiescence of ~400 years. Long shaking records are however still lacking in a large portion of the along-strike extent of this subduction zone segment, resulting in a knowledge gap of over 600 km long and thus often ambiguous cross-correlations. Also, quantitative estimations of the timing and spatial extent of these events are still lacking due to large uncertainties. These arise from inconsistencies in the applied dating techniques, variable age precision, and the mostly unclear relationship between depositional earthquake imprints and rupture characteristics. The new '*QuakeScene Chile*' project aims to push the frontiers of subduction-zone paleoseismology by i) retrieving additional records from several lakes in the Chilean lake district and on Chiloé Island to fill the knowledge gap, ii) developing a new chronological toolbox to improve synchronicity assessment between different sites and archives, and iii) applying ground-motion modelling to establish the missing link between sedimentary shaking evidence and seismological earthquake parameters. We present an overview of past and ongoing work within the framework of this project.

Hydroacoustic and bathymetric data of the Japan Trench collected during IODP Expedition 386

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Expedition 386 “Japan Trench Paleoseismology” (13th April-1st June 2021) collected giant piston cores, hydroacoustic data and high-resolution bathymetry from 11 trench-fill basins along the Japan Trench. Cores were collected in water depths of 7,445-8,023 m below sea level.

The objectives of Expedition 386 were to: (1) Identify the sedimentological, physical, chemical, and biogeochemical proxies of event deposits in the sedimentary archive that allow for confident recognition and dating of past MW 9 class earthquakes; (2) explore the spatial and temporal distribution of such event deposits to investigate along-strike and time-dependent variability of sediment sources, transport and deposition processes, and stratigraphic preservation; and (3) develop a long-term earthquake record for giant earthquakes.

The cruise collected bathymetry and 575 line kms of sub-bottom profiles (as grids) in the 11 basins. Preliminary observations indicate that northern Japan Trench basins have a different bathymetric and hydroacoustic character to the central and southern Japan Trench basins. Bathymetric character in the northern basins is more diffuse than in basins in the central and southern areas, which tend to have sharp topographic ridges bounding the basins to the east and west. The northern basins also tend to have thick (>10m) packages of acoustically transparent materials forming marker horizons between basins, whereas the central and southern basins tend to have thinner, isolated acoustically transparent layers. Evidence of faulting is preserved in one of the northern basins, and there are some interesting relationships between basal highs and basin fill that indicate fluid mobilization.

Work is ongoing in correlating our data to the piston cores of upper Pleistocene to Holocene stratigraphic successions. Preliminary results reveal several potential giant earthquake-related event beds.

IODP Expedition 386 Science Party:

Ken Ikehara; Michael Strasser; Piero Bellanova; Morgane Brunet; Zhirong Cai; Antonio Cattaneo; Tae Soo Chang; Jeremy Everest, Katharina Hochmuth; Kanhsi Hsiung; Takashi Ishizawa; Takuya Itaki; Kana Jitsuno; Joel Johnson; Toshiya Kanamatsu; Myra Keep; Arata Kioka; Lena Maeda; Christian Maerz; Cecilia McHugh; Aaron Micallef; Luo Min; Dhananjai Pandey; Jean Noel Proust; Troy Rasbury; Natascha Riedinger; Rui Bao; Yasufumi Satoguchi; Derek Sawyer; Chloe Seibert; Maxwell Silver; Susanne Straub; Joonas Virtasalo; Yonghong Wang; Ting-Wei Wu; Sarah Zellers

A first step towards separating earthquake cycles' signals in palaeo sea-level records

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Relative sea-level (RSL) changes in northwest America (from British Columbia to Oregon) are influenced by both glacial isostatic adjustment (GIA) and earthquake cycles, on timescales of decades to millennia. Those processes are crucial to understanding the drivers of RSL changes temporally and spatially, because the region sits close to the North American ice sheet complex (Cordilleran and Laurentide ice sheets) of the last glacial period and is home to a convergent plate boundary (the Cascadia subduction zone). Here, we focus on the signal from earthquake cycles.

To study the contribution of earthquake cycles to RSL changes, a geodynamic model which can accurately simulate the vertical deformation throughout a cycle is needed. In this study, we aim to reproduce the coseismic, postseismic and interseismic deformation after the 1700 Cascadia megathrust earthquake with a 3-D viscoelastic finite-element model, which includes a realistic subduction zone geometry, realistic mechanical properties (elastic, viscous, and frictional), and heterogenous rupture patterns. Model-predicted interseismic deformation (both vertical and horizontal) is compared to contemporary geodetic observations to evaluate model performance and constrain its mechanical properties.

This study not only serves as a stepping stone to quantify earthquake cycles' contribution to RSL changes on the longer timescales, but it also provides a tool to potentially tackle earthquake-cycle-related problems (e.g., determination of earthquake recurrence intervals and rupture patterns) at subduction zones.

Testing the hypothesis of a nonpersistent rupture boundary at Sitkinak Island, Alaska.

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Spatial and temporal patterns of megathrust ruptures prior to the 20th century remain unclear. Geological approaches using coastal sediments provide alternative means for constraining the chronology and characteristics of earthquakes over millennial timescales. Sharp lithological contacts indicating rapid changes in environment are key indicators of vertical land-level changes. Extensive palaeoseismic research has been conducted along the Alaska-Aleutian subduction zone in the eastern extent of the great 1964 (M_W9.2) rupture, and recent reconnaissance investigations southwest of Kodiak Island have begun to illuminate patterns of deformation including the possibility of nonpersistent rupture boundaries. At Sitkinak Island, southwest of Kodiak Island, observations by eyewitnesses during the 1964 rupture have been interpreted to suggest uplift on the northeast coast, while palaeoseismic evidence suggests subsidence in the southwest. This difference and variations in uplift and subsidence from palaeoseismic records prior to 1964 at the south lagoon have been interpreted as evidence of a nonpersistent rupture boundary where subsidence is interpreted to record ruptures arresting close to Sitkinak Island, and uplift indicates rupture through the boundary between the Kodiak and Semidi sections. Coastal geomorphology also hints at longer term differences between the coasts, with evidence of coastal marsh submergence on the southwestern side of Sitkinak Lagoon and emergence on the northeastern side. To further test the nonpersistent rupture boundary hypothesis, we present two sediment cores (~1.3 m) collected from a ~350m bank exposure at the northern lagoon. Sedimentology of the section reveals alternating peat and silt units that may indicate land-level changes from prehistoric earthquakes as well as tephra deposits that may aid in correlations. The peak in Cs^{137} occurring in AD 1963 is recorded in the sediments. This suggests that the record captures 1964, although there is no clear stratigraphic evidence for co-seismic uplift or subsidence associated with this earthquake at the site. Eight new radiocarbon dates indicate that the site dates to 2340-2433 cal yr BP. Additional microfossil, geochemical, and sedimentological analysis will be conducted to understand the deformation history of the northern coast of Sitkinak Island over the past ~2500 years and compare it to the existing palaeoseismic record ~6 km southwest.

Geological evidence of an unreported Chilean tsunami highlights the importance of combining geological and historical records in tsunami hazard assessment

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Assessing seismic and tsunami hazards commonly relies on historical accounts of past events. While such chronicles are often too short to account for variability in earthquake size, rupture style, tsunamigenesis and the existence of supercycles, even where long written histories exist, records may be biased by temporal gaps due to historical circumstances. We demonstrate that this is the case for the area affected by the magnitude 9.5 1960 Chile earthquake. Historical records document four great earthquakes (M8+) in the last 450 years in this region, but while devastating tsunamis are known to have accompanied earthquakes in 1575, 1837 and 1960 CE, there is no such record of inundation in 1737. The lack of reports of tsunami inundation from the 1737 south-central Chile earthquake has been attributed to either civil unrest or a small tsunami due to deep fault slip below land. Here we cross-check the historical record using a coastal sedimentary record from Chaihuín, a tidal marsh 15 km southwest of Valdivia, close to the region of maximum 1960 slip. Tidal marshes are low energy intertidal settings that may preserve evidence for abrupt co-seismic changes in land level and inundation by extreme waves. We conduct sedimentological and diatom analyses of tidal marsh sediments within the 1737 rupture area and find evidence for a locally-sourced tsunami consistent in age with this event. The evidence is a laterally-extensive sand sheet coincident with abrupt, decimetric-scale subsidence. Coupled dislocation-tsunami models place the causative fault slip mostly offshore rather than below land, as had previously been assumed from the absence of historical accounts of a tsunami. Whether associated or not with the 1737 earthquake, our findings reduce the average recurrence interval of tsunami inundation derived from historical records alone, highlighting the importance of combining geological and historical records in order to obtain robust long-term patterns to inform seismic and tsunami hazard assessment.

Submarine Landslide Controls and Outer Wedge Variations in the Negros–Sulu Trench System, Philippines

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Many catastrophic earthquakes and tsunamis have occurred along active trenches, and some of these tsunami events were found to either be amplified or induced by earthquake-triggered submarine landslides. In the Philippines, one of the less-recognized active subduction zones is the Negros–Sulu Trench System (NSTS) in the Sulu Sea that is capable of generating strong earthquakes and tsunamis. In this study, we characterized the outer wedge variations in the forearc margin of the NSTS and delineated submarine landslides and their morphometric parameters, submarine canyons, and lineaments. Terrain and morphometric analyses were performed using 20-m resolution local bathymetry data to delineate these submarine features. Lineaments are mainly distributed along the outer wedge, in which previous seismic profiles revealed thrusted sediments and high-angle reverse faults. The NSTS is divided into four segments based on orientation and width variations of the outer wedge. Heterogeneous sediment influx, convergence rates, and subduction processes are inferred to influence these variations. With more than 1,200 submarine landslides delineated, the L function suggests significant clustering at various distances, indicating heterogeneity and underlying geological and geomorphological controls. Matrix correlations of kernel density bands indicate that submarine canyons strongly influence the occurrence of submarine landslides as these conduits of terrestrial sediments induce rapid loading that preconditions slope failures. Getis-Ord Gi* reveals significant localized clusters of large- and small-volume submarine landslides and those with high and low length-to-width ratios (L/W). Regions with significantly low volume and high L/W occur in submarine canyon systems, whereas those with low L/W often occur along the outer wedge and abyssal plain. Significantly large-volume submarine landslides are clustered in various areas but are generally found on steeper slopes and at relatively deeper portions than those with significantly small volume. Oversteepening of the outer wedge due to seamount collision of the Cagayan Ridge is interpreted to induce the large-volume submarine landslides clustered in the northern Negros Trench segment. This new information on the spatial distribution and controls of submarine landslides in the NSTS is essential in hazard assessment of coastal areas susceptible to tsunamigenic submarine landslides.

Shaking-induced lake processes identify a previously unrecognized earthquake-triggered carbon sink and suggest potential use as paleoseismograms

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1. Cascadia Paleo Investigations

Recent research on the historic portion of the sedimentary record from a small lake near the California/Oregon border reported micron-scale sedimentological changes through disturbance deposits allowing them to be attributed to floods, an inslab or crustal earthquake, and a subduction earthquake. Changes through the earthquake deposits suggest that lake processes in response to ground motions can be identified from these sedimentological characteristics. Whereas the inslab or crustal earthquake, interpreted as a ~M7 from historic felt reports, caused the landslide dam to fail as represented by lake-wide slope failure deposits, the subduction earthquake, interpreted as a ~M9 based on paleoseismic evidence and historic data, resulted in a deposit interpreted to be the result of liquefaction. Evidence also suggests that sustained ground motions from the subduction earthquake resulted in flocculation of organics in the water column, producing a long organic-rich tail , a previously unknown earthquake-triggered carbon sink in lakes. This presentation summarizes how these lake processes can be used to bracket earthquake ground motions to better understand the spatial pattern of ground motions, and potential hazards, at inland locations throughout Cascadia where the hazard potential is greatest.

Recognizing megatsunamis in Mediterranean deep sea sediments based on the massive deposits of the 365 CE event

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The Mediterranean Sea hosts two subduction systems along the convergent Africa-Eurasia plate boundary that have produced strong ground shaking and generated tsunamis. Based on historical descriptions and sedimentary records, one of these events, in 365 CE, impacted a broad geographical area, including tsunami evidence for distances of 700-800 km from the source event, qualifying it as a ‘megatsunami’. Understanding how megatsunamis are produced, and where they are more likely, requires a better understanding of the different secondary processes linked to these events such as massive slope failures, multiple turbidity current generation, and basin seiching.

Our sedimentary records from an extensive collection of cores located in distal and disconnected basins, identify turbidites which are analyzed using granulometry, elemental (XRF), micropaleontological, and geochemical data in order to reconstruct their coastal or marine source. The depositional units of the 365 CE event, when viewed across multiple geomorphological locations of the marine depositional sites (canyon mouth, abyssal, isolated higher basin), demonstrate a complex sequence of processes triggered by the megatsunami wave propagation.

The 365 CE basin floor sediments are a mixture of inner shelf and slope materials implying that the tsunami wave produced multiple far-field slope failures that resulted in stacked basal turbidites. The sediment from the European and African margins was remobilized and transported by tsunamis to abyssal depositional sites and isolated basins during the catastrophic event. Sediment content from terrestrial and coastal sources, as shown by C/N and $\delta^{13}C_{org}$ data and abundant shallow water components in isolated basins, indicates that tsunami backwash or tsunami triggered slope failure processes entrained coastal/inland sediment and transported it into the deep sea even in the absence of canyons, probably through large-scale sheet-like flows. The tsunamigenic origin of the deposit is supported by coastal effects of the 365 CE Crete tsunami because resedimented deposits, erosional features and transported boulders with similar age, are reported around the Mediterranean Sea.

This is significant for rectifying and resolving where risk is greatest and how cross-basin tsunamis are generated. Based on these results, estimates of the underlying deposits from the same locations were interpreted as possible older megatsunamis.

Is rapid climate warming causing hypolimnetic anoxia in lakes? Exploring the climate-anoxia link in the Late-Glacial sediments of Soppensee, Switzerland

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Recently, many lakes transitioned into stratified eutrophic systems due to nutrient additions from their catchments. Associated hypoxia typically deteriorates lake water quality, threatening aquatic ecosystems and water resources. Often, hypoxia and anthropogenic eutrophication interact in a positive 'chemical feedback' in which eutrophication-induced hypolimnetic anoxia prompts internal phosphorous (P)-loading which, in turn, sustains eutrophication. It is poorly understood whether this 'chemical feedback' also operated under natural pre-anthropogenic conditions and to what extend such events were reversible.

We test the existence of a pre-anthropogenic chemical feedback in well-studied Soppensee, a postglacial kettle-hole lake in Switzerland. Here, the Bølling warming (~14,700 cal. yr b2k; GI-1*e*) prompted an event with hypolimnetic anoxia. We investigate the sequence of biogeochemical lake responses –eutrophication, hypolimnetic anoxia, dynamics of algal communities, nutrient cycling, and chemical feedback – throughout Greenland Interstadial GI-1*e* which ended by abrupt cooling in the Older Dryas (~14,080 cal. yr b2k).

Our methods include XRF (elemental composition), hyperspectral imaging (bulk sedimentary pigments), HPLC (specific sedimentary pigments) and sequential extraction of phosphorous. We interpret total chlorophylls and diagenetic products (TChl) as a proxy for aquatic productivity and bacteriopheophytins (Bphe-*a,e*, purple and green sulphur bacterial biomarkers) as a proxy for hypolimnetic anoxia and (semi)-permanent lake stratification. The Redox-labile Fe-P preserved in sediment is a qualitative indicator for reductive dissolution of Fe-(oxyhydr)oxide bound P and internal P-cycling.

Preliminary results show that, before the Bølling, TChl, Bphe and all phosphorous fractions were low, suggesting oligotrophic well-mixed conditions. With the beginning of the Bølling warming, we observe an immediate increase of TChl with strong eutrophication. With a delay of a few years, Bphe-*a,e* peaked and permanent stratification with hypolimnetic anoxia was established. All sedimentary P fractions remain low suggesting that P is mainly recycled. After the warm Bølling (~700 years, ending in the Older Dryas cooling), eutrophication and lake stratification broke abruptly, and sedimentary Fe-P and Ca-P concentrations increased simultaneously. Although less pronounced, this cycle repeated in the Allerød, suggesting that past anoxia events were partly reversible. In our case study, we conclude that the eutrophication-anoxia chemical feedback also operated in Late-Glacial times and was triggered by rapid climate warming.

Synchronizing the Western Gotland Basin (Baltic Sea) and Lake Kälksjön (central Sweden) sediment records using common cosmogenic radionuclide production variations

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Multi-archive studies of leads and lags in the climate system, as well as archive-specific thresholds require synchronous time-scales. Aligning common variations in short-term cosmogenic radionuclide production via curve fitting methods provides a tool for the synchronization of natural environmental archives. Based on this approach, we synchronize ^{10}Be records from brackish Western Gotland Basin (WGB, Baltic Sea) and Lake Kälksjön (KKJ, central Sweden) sediments to the ^{14}C production rate time-series inferred from the IntCal20 calibration curve during the period ~6400 to 5200 a BP. Before the synchronization, we assess and reduce non-production variability in the ^{10}Be records using ^{10}Be/^{9}Be ratios and common variability with the significantly correlated TOC record from KKJ sediments based on regression analysis.
The synchronizations to the IntCal20 ^{14}C production time-scale perform decadal to multi-decadal refinements to the WGB and KKJ chronologies. These refinements place the investigated WGB and KKJ sediment records on the IntCal20 ^{14}C time-scale and reduce the previously centennial-scale chronological uncertainties between both records to about ± 20 years. Placing the WGB and KKJ sediment records on one time-scale with minimized chronological uncertainties opens the possibility for the investigation of possible time-transgressive environmental changes in the marine-terrestrial Baltic ecosystem, with high temporal precision.

Using a multiproxy approach to interrogate the terrestrial impacts of the Laschamps geomagnetic excursion (ca. 41 ka BP) at Ioannina, NW Greece.

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The palaeoenvironmental archive at Lake Ioannina presents an important opportunity to study vegetation responses to past changes, including climatic variability and changes in the Earth's systems. A new, high-resolution pollen study between 46 and 40 ka BP reveals vegetation changes in response to climate variability on millennial timescales. Overprinting this climatic variability is an abrupt, sub-centennial, disturbance event dated to ca. 41.5 ka BP. Here, we utilise a decadally-resolved, multiproxy reconstruction to identify potential drivers of this vegetation disturbance event at Ioannina. Through study of pollen geochemistry, we reconstruct changes in terrestrial UV-B between 46 and 40 ka BP to see if the collapse in tree populations observed at Ioannina is related to changes in the Earth's magnetic field intensity associated with the 41 ka BP Laschamps geomagnetic excursion. Additionally, we use detailed micro and macro-charcoal analysis to determine whether simultaneous changes are observed in the fire regime at the site. Finally, we present the results of diatom analysis to reconstruct changes in the hydrological system to rule out a local climatic or hydrological driver for the vegetation disturbance. Through our detailed study, we aim to provide some of the first insights into the environmental response to changes in strength of the Earth's magnetic field around the timing of the Laschamps excursion, and potential subsequent impacts on human life.

Warm Younger Dryas summer temperatures in the South Carpathians

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Assessment of Late Glacial (LG) summer climate change suggests that the south-eastern part of the European continent experienced lower amplitude summer temperature fluctuation during stadial-interstadial transitions in comparison with NW Europe. In this study we present a new LG and Early Holocene summer temperature record based on fossil chironomid assemblages. The study site, Lake Latoritei (Pareng Mountains, 1530 m a.s.l.) was analysed at high resolution for chironomid and other paleoecological indicators. Using the joint Norwegian – Swiss transfer function, the reconstructed chironomid-inferred temperature pattern shows some differences from the NGRIP $\delta^{18}O$ record and other European chironomid-based reconstructions; however, it is consistent with the chironomid results of Lake Brazi (Retyezat Mountains, 1740 m a.s.l.). Summer air temperature at Lake Latoritei increased by ~ 3°C at the Oldest Dryas/Bølling transition (GS-2/GI-1) and reached 8.1-10.8°C during the LG interstadial. The Younger Dryas (GS-1) climate reversal is shown by only a weak decrease (~1 °C), while a slow temperature increase (9.7–11 °C) is observed in the second half of the period. We also performed cryptotephra analysis for the GI-1-GS-2 period showing that the region was reached by the ash fall of the Vedde Ash eruption (12,140 ± 40 cal BP), as well as by several unknown tephra. In other European sections, where the Vedde Ash eruption was found, the onset of the YD summer mean air temperature decline started at ~12,710 cal BP (Lake Kråkenes, Norway), at ~12,650 cal BP (Soppensee, Switzerland), at ~12,730 cal BP (Lake Bled, Slovenia), while in our record the chironomid-based T_{July} decline is dated to 12,500 cal BP. However, the old age effect detected during radiocarbon dating caused large uncertainties in the determined ages. At the Holocene transition a T_{July} temperature increase of ~2 °C was observed within 50 years. Prior to the Preboreal Oscillation (PBO), the mean summer air temperature was 12.5 °C. During the PBO, the temperature reconstruction shows a decrease of 1.8 °C. This cold event coincides with cooling in the Greenland ice core records and other European temperature reconstructions. Following the PBO, summer air temperatures increased to ~12.8 °C in the Early Holocene.

Assessment of the effect of soil salinity on bacterial diversity and community structure in a semi-arid area of Northern Tunisia

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Due to climate change, water resources in many regions have reached their natural limits, resulting in environmental and socio-economic problems such as agricultural drought and soil salinization. Therefore, soil salinization is likely to increase further in irrigated perimeters in arid and semi-arid areas worldwide. However, soil is a dynamic system whose functionality is related to the relationships between physicochemical properties and soil microorganisms. Most studies are limited to the top 30 cm of soil, but few works have been made about this topic in soil depth, particularly in semi-arid regions. This study aims to assess the effect of soil salinity on the bacterial community structure in upper and deeper soil horizons from an agricultural land in Northern Tunisia dedicated to apple and pear growth.

Twenty-three samples from the soil surface (0-10 cm) and subsurface (30-50 cm) were randomly taken in the study area. The study site is in the lower Medjerda River valley basin, Manouba, Tunisia, and is characterized by Quaternary deposits composed of sand and clay. Results showed that electrical conductivity ranged in soil from 0.6 mS. cm-1 and 5.0 mS. cm-1, pH ranged between 7.9-8.7, and soil organic C between 0.59-2.85 %. There were differences in the diversity and relative abundance of bacteria in the topsoil and deeper soil layers, assessed by DNA metabarcoding. Bacterial community was strongly related to soil physicochemical properties, including soil salinity.

Thus, studying the interrelationships between soil physicochemical properties and soil microorganisms could be an effective tool to understand the dynamics of microorganisms, and to determine the mechanisms of their adaptation to soil salinity.

Geochemical characterisation of tephra to improve marine, terrestrial and ice core chronologies in Antarctica

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Global compilations of paleoclimatic change currently exhibit a northern hemisphere bias. This challenges our ability to use these datasets to validate, evaluate and calibrate models of past climate change and to understand regional to hemispheric patterns of atmospheric and oceanic circulation changes. Antarctic paleo records have made significant contributions to understanding past changes in atmospheric CO2, temperature, ice sheet thickness and extent as well as ocean dynamics. Linking these changes and investigating leads and lags across ice, marine, lake and terrestrial records requires well-defined chronological reference points such as discrete tephra, produced by significant volcanic eruptions.

Whilst tephrochronology has been applied to a variety of Antarctic records, few studies systematically cross-correlate tephra across lacustrine, marine and ice core records in this region. This project aims to form a tephrochronological framework for Antarctica using numerous cores extracted from these environments and improve the chronologies of proxy temporal records of past climate change from the Antarctic Peninsula and the Sub-Antarctic Islands in the Southern Ocean.

We will identify suitable records for tephrochronology by scanning through cores and identifying peaks of tephra and undertake geochemical analyses using EPMA and LA-ICP-MS techniques for shard-specific chemical assay. Correlation of geochemical signatures of the tephra peaks will be conducted using reference material from known eruptions and deposits to build a tephrostratigraphic framework.

Integrated stratigraphy of the NDT-09 marine record: a ~15 ka-long depositional history in the epiclastic-volcanoclastic domain of the Marsili Basin (southern Tyrrhenian Sea)

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This research presents preliminary results obtained from an integrated stratigraphic study of core NDT-09, carried out in the frame of INGV-AMUSED (*A MUltidisciplinary Study of past global climatE changes from continental and marine archives in the MeDiterranean region*") project activities. The core was recovered by CNR-ISMAR (former IAMC) during the oceanographic cruise NextData2016 in the western rim of the Marsili Basin at a water depth of 3359 m. The succession is 5,7 m long and it is characterized by hemipelagic mud sediments frequently interrupted by primary and secondary tephra deposits along with turbidites. The record has been studied by means of micropaleontology (calcareous nannoplankton, planktonic and benthic foraminifera), sedimentology, petrophysics, paleomagnetism and geochemistry (X-Ray Fluorescence, cosmogenic radionuclides, oxygen isotope). The chronological framework is provided by ^{14}AMS datings and tephrochronology (macro- and cryptotephra). The occurrence of the Neapolitan Yellow Tuff related tephra dates the bottom of the succession at ca.15 ka, whereas the decrease of the abundance of *Emiliania huxleyi* >4 µm at 480 cm and the increase of *Florisphaera profunda* at 430 cm indicate the onset of the Holocene interstadial period. The stratigraphic approach allowed us to "integrate" all the obtained data, to combine proxies (eg. total coccolith abundance vs Ca/Fe and Ca/Ti profiles to identify low and high detritic inputs) and to define a sequence of depositional events along the record. This latter is characterised by a prevailing epiclastic-volcanoclastic sedimentation (locally exclusive) due to the significant influx of deposits from the Aeolian Arc, the Neapolitan volcanoes and Ischia Island. Chemistry of single glasses of volcanic turbidites, in particular, reveals a homogenous trachytic to latitic composition, typical of distinctive Campi Flegrei products, thus suggesting a recurrent reactivation of flow transport from a single or multiple source areas.

The Holocene and terminal Pleistocene tephrochronological record from annually resolved lakes in East Anglia: implications for the integration of palaeoclimate, palaeoenvironmental and archaeological records in the North Atlantic and Northwest Europe

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Tephrochronology has become a key tool in the synchronisation of a range of palaeo-records, from past climate to archaeology. Much of the work on lake records has mostly focussed on the last glacial period but recently several lake records, some of them annually laminated, have started to show the potential for far travelled tephra to be a key tool in the synchronisation of Holocene records in the North Atlantic and Northern European realm. This builds on the long history of analysing peat sequences in areas such as Scotland and Northern Ireland. Here we present a complete tephrostratigraphic record for the whole Holocene and end of the Last Glacial from East Anglia, along with a complete Holocene Bayesian age model for a critical varved lake record from the region, Diss Mere, Norfolk. This region has demonstrated that it is pivotal for understanding the potential for tephra dispersal from multiple volcanic sources across Northwest Europe and the North Atlantic, as it receives tephra from multiple volcanic sources. We present a total of 11 new tephra from the late Holocene and the terminal Pleistocene from Diss and other sites in the region, to add to the currently published tephra record from Diss. This takes the Holocene tephra record of East Anglia to 28 tephra (all but one of which has been found in Diss among other sites), all successfully correlated to either known tephra or to volcanic centres, using major and trace element chemical analyses. We show that Diss, along with a nearby site known as the Lay, contain tephra from Iceland, the Azores, Italy and North America. We also present a high-resolution chronology for this East Anglian tephra record, based on varve counting, ^{14}C and ^{210}Pb dating, and ^{10}Be synchronisation and historic age tephra. We then use this to demonstrate the significant potential for the integration of wider records across the whole Holocene.

Impact of extreme events related to climate change on mountain areas: preliminary results from the Abruzzo region (central Italy)

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In the last decades, the interest of the scientific community on the coupling between extreme weather events and hydrogeological hazard has increased significantly. Given predictions about future climatic trends, a deeper understanding of the climatic influence on geomorphological phenomena is crucial to properly mitigate the hazard and the associated risk. Despite the numerous studies, the complexity of the interactions between climatic forcing and landscape still leaves many open questions about the triggering mechanisms of hazardous geomorphological processes like mass wasting. What is certain is that extreme rainfall events play an important role in the spatial-temporal distribution of high-elevation mass-movement events.

In recent decades Italy has been the scene of numerous extreme weather events, usually followed by phenomena such as landslides and floods that had a significant economic and social impact.

In this study we investigate the impact of extreme events on the mountain areas of the Abruzzo region (central Italy). The aim is to understand how the variation in frequency, intensity and spatial distribution of extreme events and the modification of meteorological parameters can affect the natural environment and human activities.

We collected the precipitation data of 202 stations for the period 1918-2021. The data were statistically analyzed to individuate the extreme events. In particular, we used the percentile method considering that a weather event is defined extreme if it is as rare or rarer than the 90th percentile. Successively, a landslides database has been realized by specifying the type, the date, and the geographic coordinates. Producing a landslide density map, we extracted landslides and stations located in areas with values greater than 0.4 landslides/km^2. Each landslide was paired with the nearest weather station and the precipitation values up to 30 days before the event were extracted to calculate the rainfall threshold.

The preliminary results allowed to individuate critical areas where to perform a field investigation to define the landslides predisposing and triggering factors and the local-scale impact of climate variations. This will lead to the assessment of the susceptibility of the study area to geomorphological phenomena and a better land management and resilience policies with respect to climate change.

From earthquake-triggered landslide inventories to intensity assessment: methodological workflow and preliminary results

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Earthquakes commonly trigger secondary effects, including landslides; earthquake-triggered landslide inventories are available for tens of case histories and are a key input data for hazard assessment. The spatial distribution of landslides is commonly analyzed in terms of density or areal percentage, and compared to geological, geomorphological and seismic parameters.
Here we describe a methodological workflow to derive a macroseismic field, given a polygonal landslide inventory. We express intensity using the ESI-07 (Environmental Seismic Intensity) scale, which is based only on the effects on the natural environment. ESI-07 values are assigned to each mapped landslide based on the mobilized volume, which in turn is obtained from available area-volume scaling laws.
We apply the method to more than 20 earthquake-triggered landslide inventories on a global scale, adopting a grid-approach: the study area is divided into a regular grid of 1-km2 cells and ESI-07 values are derived for each cell. We apply several area-volume scaling relations, exploring the epistemic uncertainty and either the inter-event and intra-event variability. We also derive original relations between ESI-07 and LND (Landslide Number Density) or LAP (Landslide Area Percentage).
To date, the scientific communities dealing with i) realization of earthquake-triggered landslide inventories and ii) the application of the ESI-07 scale cooperates only sporadically. We argue that the easy-to-use, standardized method proposed here provides the ground for an enhanced collaboration, with mutual benefits. Indeed, landslide inventories derived from satellite or aerial imagery usually have a high spatial resolution and allow to systematically investigate wide territories; on the other hand, the ESI-07 scale allows to compare different earthquakes in space and time.

November 23, 1980 - M6.9, Irpinia-Basilicata Earthquake, southern Italy: An updated dataset of environmental seismic effects

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The Mw 6.9 earthquake of November 23, 1980, known as the Irpinia-Basilicata Earthquake, was the strongest seismic event to hit Italy in the last century. There were 2,914 victims, 8,848 injured and about 280,000 homeless. The earthquake also induced numerous effects on the natural environment, both primary, surface faulting, and secondary, such as gravitational phenomena, ground fractures, liquefactions and extensive hydrological changes related to the flow rate of springs and rivers. The epicentral intensity is I=X either using the MCS (Mercalli – Cancani – Sieberg) macroseismic scale, or the ESI-07 (Environmental Seismic Intensity) scale, which is based only on environmental effects. Currently, there is a fair amount of knowledge about seismically induced environmental effects. There are also published compilations of effects, sorted by location, but without precise spatial location of each phenomenon. Several efforts have been made to document the environmental effects observed at the time of the earthquake, but a unified view integrating all available data is still lacking. This work aims at collecting all available data and build a comprehensive geodatabase, including information on the spatial location of these phenomena with the best possible accuracy. Data on Earthquake Environmental Effects (EEE) are collected from scientific papers, local professional geological reports, and are integrated with original field surveys. Environmental effects are then catalogued according to the ESI-07 scale guidelines. Results of paleoseismological trenching conducted across the earthquake ruptures are also included. The ultimate goal is to create a homogeneous and accurate dataset containing all the environmental effects induced by the 1980 Irpinia-Basilicata Earthquake, to fed and update extant catalogues (e.g., EEE Catalogue managed by Ispra, Geological Survey of Italy). In this way, it is possible to carry out a more complete analysis of the local seismic hazard and the environmental effects induced by it; moreover, it is possible to compare the effects induced by this earthquake with those of other earthquakes, even in other dynamic contexts, contained in similar catalogs (e.g. Catálogo de los efectos geológicos de los terremotos en España).

Understanding Earthquake-related Hydrogeochemical Responses: Results from a Long-term Monitoring Study Applied to the 2020's Monte Cristo Seismic Sequence (Nevada).

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Earthquakes are well known to affect regional surface and groundwater systems, inducing changes in water chemistry and availability. However, the mechanisms behind aquifer responses are still unclear, due to the limited and short-term data available and the other factors affecting water quality.

To overcome this issue, we undertook an 18-month hydrochemical monitoring program in the epicentral area of the Monte Cristo Range seismic sequence, which struck Nevada between May and December 2020. The monitoring network included four locations at different distances from the epicenter, presenting different hydrogeological settings. This setup allowed us to determine seismic-related anomalies in different contexts and helped us point out factors affecting changes. We measured physicochemical parameters (T, EC, pH, alkalinity, and flow rates) and collected water samples for major ions, trace elements, and water isotope analysis. We then highlighted anomalous chemical changes (i.e., above or below the average ± standard deviation range) along the seismic sequence using time series plots.

The most marked anomalies occurred at the closest site to the epicenter (*Columbus Salt Marsh):* we observed an increase in SO_4, Ca, K, Fe, Zn, and Cu coinciding with a decrease in Na, Cl and Li during the period of May and November 2020. These changes suggested a possible mixing of water within the aquifer as the main driver. A similar but less marked trend was observable after the May shock in *Fish Lake Valley*, where we assessed a slight decrease in Cl, Na and a concomitant increase in SO_4, Ca and Ba. *Willow Ranch* site, close to *Fish Lake Valley*, presented scattered changes in major ions during the whole monitoring period. However, anomalous peaks in temperature and trace elements were observed during November aftershocks, mirroring a possible upwelling of geothermal waters from which the Fish Lake Valley hot well is sourced. Finally, the furthest site from the epicenter (*Mina Dump*) did not reveal any relevant effects on water chemistry, possibly due to the reduced seismic stress affecting this area.

Our results confirmed the complexity of earthquake-related hydrogeochemical responses, influenced by hydrogeological and seismic features.

Biotite chloritization triggers seismicity: Coupling geochemistry with seismology

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Numerous small to medium-scale tremors have been felt in the Koyna-Warna Seismogenic region during the last five decades since the impoundment of the Koyna Dam in 1962. The largest earthquake with a magnitude ~ 6.7 occurred in 1967 in this small region which is bounded by the Koyna River fault zone to the west and NE-SW trending Patan fault to the east. The bulk and clay mineralogical XRD of the fracture and fault zone material of the basement granitoid of the Koyna-Warna region have revealed the occurrences of chlorite, illite, and epidote, and precipitation of calcite. Subsequent optical microscopic studies have shown the biotitic remnants within the neoformed chlorite in close association with the epidote indicating the formation of chlorite and epidote from biotite due to the reaction of element-rich fluid with host rocks.

Biotite + Al^{3+} + Mg^{2+} + Fe^{3+} + Ca^{2+} + H_2O + H^+ $\rightarrow$ chlorite + epidote + TiO_2 + H_4SiO_4 + K^+

Besides, the dissolution of plagioclase has been observed supporting the formation of illite at certain depths and the precipitation of calcite along several thin and thick fractures. Earlier studies have also revealed that this plagioclase dissolution is associated with the chloritization of biotite.

Plagioclase + Fe^{2+} + Mg^{2+} + K^++ H_2O $\rightarrow$ albite + illite + Ca^{2+} +Al^{3+}

Thus, the fluid-rock interaction promoting secondary mineralization basically resembles propylitic kind of hydrothermal alteration in the basement rocks of the Koyna Seismogenic Region. In addition, the presence of chlorite and illite-like hydrophilic clay minerals in fault and fracture zones may be responsible for triggering the seismicity in this Seismogenic Region because the absorption of water increases fluid pressure (P_f) and reduces the effective normal stress (σ_n). As a result, Critical Shear Stress (τ_c') becomes less than the effective shear stress which facilitates steady fault creep resulting in small recurring tremors.

In general, $\tau_c = (\mu \times \sigma_n) + c$

In our case, $\tau_c' = \mu \times (\sigma_n - P_f) + c$

On the other hand, the epidotes present here increase frictional strength under hydrothermal conditions and may promote unstable sliding with a large-magnitude earthquake in the future as experienced in 1967.

New hints of paleoliquefaction events across the external front of the Eastern Southern Alps in Veneto and Friuli (NE-Italy)

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Among the secondary coseismic effects, liquefaction phenomena associated to medium-to strong earthquakes are often documented in wide areas around the epicentre. Paleoseismological studies certainly represent a fundamental key to unravel liquefaction episodes of the past, beyond the historical time interval.

The paleoseismological studies conducted in the north-eastern Italy (partly in the framework of the Italian Seismic Microzonation Project), allowed to detect many unpublished case-studies of paleoliquefaction events. The investigated sites are located across the Plio-Quaternary external front of the Eastern Southalpine Chain, a SSE-verging fold and thrust belt extending all along the Veneto and Friuli prealpine border. Numerous damaging earthquakes (Mw > 5.5) struck the study area in historical times: 1511 Mw 6.3, 1695 Mw 6.4, 1873 Mw 6.3, 1928 Mw 6, 1936 Mw 6. Despite the medium-to-high seismicity, the record of paleoliquefaction evidence in the literature are scarce. However, if considering the most recent seismicity, many liquefaction events associated to seismic shaking were registered in the epicentral area of the Friuli 1976 earthquake (Mw 6.5).

In this work we present the results of paleoseismological analysis conducted along the Veneto-Friuli prealpine border aimed at the characterization of active and capable faults. The paleoliquefaction features detected in trenches involve both fine and gravelly sediments and mainly include dikes filled by sand or silt and sand blows with sparse foundered clasts. Despite the presented data are preliminary results which should be further analysed, they provide important hints for the Italian Seismic Microzonation and Seismic Hazard Assessment of the Veneto - Friuli region.

Quaternary scientific papers production in Africa, a review.

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Many studies have examined the impact of African scientists and their contribution to the worldwide scientific research, through the quantity of their publications in peer-reviewed journals. These studies have highlighted that the impact of African researcher in terms of scientific production and the quality of international publications is still under what it should be. In this study we propose to shed light on the African researcher contribution in quaternary sciences research such as surface process and quaternary geology, through a statistical analysis of African scientists contribution in comparison with worldwide scientists work.
For this purpose, we examined the representation and contribution of African and other authors using a bibliometric study of international geoscientific impact journals in the Web of science over a period of 25 years (1996 to 2021).
The results show a very low rates of scientific production of African authors for the examined period. Nevertheless, the number of publications has continuously increased, but it is still far from worldwide scientists production of the developed countries.
Indeed, some countries in the world such as USA, Japan, China, UK and Netherlands published alone more than all African countries combined.
Therefore, African countries should fil the gap in this field by developing research infrastructures and education as well as by enhancing the annual budget devoted to upgrade their research capacities.

Traps ‘n’ Maps: collecting modern pollen data across Australia to better reconstruct its ancient landscapes.

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Pollen is an important proxy for past vegetation. In Australia, the relationship between vegetation and pollen is not well constrained, even in the modern. Thus quantitative reconstructions of past plant abundance and land-cover based on palynological records cannot be precise. Traps ‘n’ Maps is a project by the Australian Research Council’s Centre of Excellence for Biodiversity and Heritage (CABAH) to establish a pollen monitoring network across major climate and biogeographic zones in Australia.

This project will help palaeoecologists move from describing “what was there” to “how much was there”. This will add a new dimension to understanding across a variety of disciplines that examine Quaternary Australia. Interactions between people, fire, fauna, and the climate are mediated by, and are reflected in, vegetation. Data will be collected using pollen traps installed and vegetation surveys conducted in transects spanning many hundreds of kilometres across the Australian continent. Collaboration with the Terrestrial Ecosystem Research Network will allow the use of existing long-term vegetation surveys.

Citizen science is also a major component of this project. Researchers are conducting a travelling “road show” in regional schools, highlighting the science being done in students’ backyards. An app is in development that will guide participants to construct a pollen trap of their own from readily available hardware and conduct a basic vegetation survey. Ultimately, Maps ‘n’ Traps will contribute a leap forward in our ability to reconstruct past Australian landscapes and create a powerful tool for public engagement.

: Rethinking data sharing in phytolith research: from FAIR phytoliths to key insights for the future

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Our project 'Increasing the FAIRness of phytolith data', funded by EOSC-Life, is striving to set the basis for implementing the FAIR (Findable, Accessible, Interoperable and Reusable) data principles within the phytolith research community. Phytoliths are micro-botanical remains that are formed within the cells of living plants. They can be used to address archaeological questions concerning anthropogenic plant exploitation and landscape changes.

The phytolith community has been making efforts to standardise data through the development of a common nomenclature and other guidelines. However, the routine adoption of these standards has not been straightforward. Data sharing is minimal and data is often exclusively within paywalled published articles rather than in open repositories.

An assessment of open science practises in phytolith research (Karoune 2020) found that only a small percentage of research provided reusable data. These findings initiated the FAIR Phytoliths project to take the first steps along the FAIRification journey.

The FAIR Phytoliths project has engaged with our community to find shared views on opening up research. We have also conducted an assessment of publications containing primary phytolith data and associated methods to fully investigate the key variables needed to improve data sharing in line with the FAIR principles.

This presentation will share the results of this work and the FAIR guidelines that we have drawn up with community support. We will discuss what this means for future phytolith research and the wider learnings that can be taken from this project for the archaeological community. We hope this work will initiate more sustainable data sharing practices in the future for phytolith research and related disciplines.

Geochemistry of Middle Pleistocene fossil termite nests (Calitzdorp, Western Cape,South Africa)

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Fossil termite nests (termitaria) are commonly replaced by calcium carbonate and preserved as resistant, dolomitised material. A typical process for precipitation in pedogenic carbonates is the downward migration of saturated carbonate solutions from the vadose zone (which lies between the groundwater and water table). Carbonate chemistry can therefore be used to comment on palaeoenvironmental conditions like vegetation and climate. In South Africa, carbonates from fossil termite mounds (Heuweltjies) interpreted to have been made by termite activity, have successfully been studied to determine palaeovegetation and palaeoclimate trends using carbon and oxygen stable isotopes. Here, we evaluate two calcretised Middle Pleistocene termitaria preserved in a well-developed soil profile near Calitzdorp (Western Cape, South Africa) to determine their palaeovegetation and palaeoclimate signals. The bulk rock mineralogy and geochemical analysis indicates that the fossil nests comprise 27 wt.% of carbonate minerals, 25% of which is dolomite and 2% calcite. Targeting carbonate precipitate enriched zones of the nest specimen, which are interlayered with clastic sediments, we assessed their δ13C and δ18O values. δ13C ranges between -3.45‰ to -0.69‰ PDB and δ18O ranges between 28.49‰ to 31.33‰ SMOW. These δ13C signatures suggest a dominance of plants with a C4 photosynthetic pathway at the time of calcretisation. C4 plants prefer warmer climates regimes which is supported by the range δ18O values which suggests that the climate in Calitzdorp was likely warmer than today.

Morphology, radiocarbon dating and stable isotopes analysis from eggshell of extinct ostrich from Central Tapi River Valley, India: Paleoanthropological significance

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The ostrich is important for Quaternary scientists trying to understand human adaptations, cultural practices, and Late Pleistocene extinction patterns. Modern ostrich is adapted to open, arid environments in Africa and southwest Asia. Their range extended to South Asia and arid northwest China until 7500 years ago. The Central Tapi River Valley (CTRV) is important because among hundreds of ostrich eggshell (OES) fragments recovered from archaeological and paleontological sites across India, three from CTRV preserved intentionally engraved designs similar to cultural specimens from Africa and elsewhere. They represent the earliest dated, engraved artistic expression of prehistoric humans in India. These artefacts compliment the evidence for manufacturing drilled beads on ostrich eggshells from sites up to 50,000 years old (ka) in Africa, India, and China. The eggshell inner (columnar crystal/mammillary) layer is resistant to diagenesis. This layer provides reliable radiocarbon dates, and its stable carbon and oxygen isotopes of OES are valuable proxies for reconstructing paleoenvironmental conditions. Ostrich is herbivorous, so OES $\delta 13C$ reflects the average dietary proportions of C4 and C3 plants during the breeding season. Ostrich is not obligate drinkers, so they acquire most water from plants. Leaf water transpiration results in high enrichment in leaf $\delta 18O$ particularly when there is low humidity. OES $\delta 18O$ thus reflects relative humidity.

We report the discovery of an OES fragment from the CTRV. The specimen was subjected to various analytical procedures, including the microscopic study of surface morphology, thin section analysis under a polarizing microscope, radiocarbon dating, and stable carbon and oxygen isotope analysis. The analysis of this specimen, dated to 53,200 ± 1200 cal bp, was compared with reported records of OES, including modern and extinct species, and regional geologic and archeologic records to understand its paleoanthropological and paleoenvironmental significance.

New information on mortuary practices and subsistence of terrestrial hunter-gatherers from the highlands (Cerro Guido/Sierra Baguales) during the late Holocene in southern Chilean Patagonia

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The geographical area of Cerro Guido and Sierra Baguales (Province of Última Esperanza, Magallanes, Chile) is a territory characterized by low steppe or pampa plains, large ravines, current ephemeral watercourses and others with large tributaries, as well as mountains with high accessible plateaus and summits that are difficult to access. In summer the territory is open and easily accessible, while in winter snow covers every space. Results obtained during the 2020-2022 archaeological campaigns give so far an antiquity in the human occupation of the sector of up to ca. 2400 years BP. The main characteristics observed have been the supply of varied and good quality lithic raw materials in high mountain range sectors (~ 1500 masl) and the hunting and gathering of large fauna in ravines and valleys with the main use of the guanaco (Lama guanicoe) as the most exploited species. Previous antecedents on the customs of these human groups indicate mortuary practices with the recurrent use of high areas for the burial of individuals in chenques, being the most recognized the one called “Chenque de Cerro Guido” or “Guido 1”, arranged in the highest point of the homonymous hill and characterized by multiple burials having been reused in a period between ca. 500 and 1150 years BP. New antecedents have allowed us to recognize the use of other spaces for the burial of skeletons evidenced through the use of a rock shelter, allowing us to broaden the vision of funerary practices in this sector. The components discovered so far help to improve the information about the customs and lifestyles of terrestrial hunter-gatherer groups from the interior to the extreme south of Patagonia.

Unique Zoological Nomenclature for World-Wide Databases, is it possible?

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Paleoenvironmental research data are a resource that must be managed in a way that provides the entire global-change research community with the tools to find, access, and manipulate quickly the data needed for a particular investigation. Much of the research into the responses of species and communities to climate change is based on recent historical data, and although climate has changed significantly since the start of the Industrial Revolution, a broader suite of global climatic changes have occurred in the past. It has identified several types of data that need to be given high priority for global change studies. The first priority is the original "raw" or primary paleoclimatic, paleoecologic, and paleoceanographic data, including associated chronological information. The power of paleoecological data lies in the temporal dimension: fossil deposits contain repeated samples through time, drawing from different climatic and environmental contexts. For creating a complete database that could include much of above data, several criteria have to be decided, like locality (how much information is needed?), chronology (absolute, relative, etc.), and taphonomy (qualitative and/or quantitative ecofats) issues, but one contentious issue, mostly for the great importance for any database, are the taxonomic names assigned to the specimens. Establishing a conventional and unique zoological nomenclature used for a database, considering similarities and differences between New and Old worlds systems, is necessary for a database have World-wide usefulness. Species names for extant species could follow ASM recent database, but those for the fossil record are still awaiting a unique endeavour, in agreement with current taxonomic practices.

A MaxEnt predictive modelling for palaeontological sites in the Siwalik Hills: A case study from the Pinjore Formation of the Siwalik Hills north of Chandigarh, northern India

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The Pinjore Formation of the Upper Siwalik Hills north of Chandigarh, northern India, is India's only continuous and most extensive Early-Middle Pleistocene deposit. It is well-known for its rich deposits of fossilised vertebrate faunal remains, chronologically ranging from 2.58-0.63 Ma. However, most have been reported as surface finds of an unconfirmed geological association. In order to better understand the Pinjore biostratigraphy, new surveys were initiated in the region in November 2020. A MaxEnt predictive model was generated to guide the surveys in the region. The main objectives of this model were: 1) to identify new fossil scatters closer to the context. 2) to evaluate the applicability and accuracy of predictive models generated using MaxEnt for identifying fossil localities in the Siwalik Hills region. 3) to generate a replicable predictive model through this case study. Primary data consists of environmental variables that include slope, aspect and NDVI (vegetation index). The input data used 14 previously known fossil localities from the study area. The model's accuracy was evaluated through field surveys concentrated around regions predicted with a high-moderate possibility for the presence of fossil sites. As a result, six new fossil localities, with multiple scatters, have been identified in the Pinjore Formation of the Siwalik Hills north of Chandigarh. Further efforts are now being directed towards improving the model enhancing its spatial resolution.

Hunter-gatherers of the central Narmada Basin: a unique and prolonged survival

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The region of central Narmada Basin (CNB) is bounded by heavily forested zones of Vindhyans and Gondwanas, famously known as the Satpura forest. Sitting in the centre of India, the region is home to diverse flora and fauna. CNB was explored, surveyed and excavated during 2015-2019 for the author's doctoral work. The project aimed to locate open-air sites and microlithic occupations in this region. Extensive surveys covered a 326 km area, bringing to light a high number of (225) microlithic occurrences. The unique ecological setting of this forested area yielded 15000 non-geometric microliths indicating primarily hunting-based subsistence. Eighteen major sites were selected for microlithic collections, which were later morphometrically analysed in the lab. Luminescence dating has been carried out at six sites from this region, supporting the sustenance of these prehistoric Homo *sapiens* in the CNB. This ecological niche supported the hunter-gatherer lifeways for at least ~50-1kya, i.e. Late Pleistocene to Late Holocene. It is possible that this ecologically resourceful region provided these hunter-gatherer communities to sustain in this zone with microlithic technology mostly isolated from the surrounding regions. The region has not yielded any cultural artefacts other than the lithics from Lower Palaeolithic to microlithic. It is indeed a unique ecological and geological niche that prolonged the existence of microlithic-producing hunter-gatherers commonly thought to have transitioned into an agriculture-based economy mainly after the 8kya (Mesolithic period). Such a detailed study of this region provides a balanced approach to understanding microlithic sites in an open-air context and their prolonged use by the hunting-gathering communities. This paper/poster aims to represent a wholesome result-oriented research that speaks about a human-ecology-landscape-technology relationship in the central Narmada Basin.

Ostracods as proxies in Lake Stechlin, NE Germany – an actualistic approach

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Actualistic studies are a necessity for the development and improvement of proxies for palaeoenvironmental reconstructions. For ostracods, several proxies that have been established and used frequently in, e.g., palaeoenvironmental, palaeoclimatological or geoarchaeological studies, have never thoroughly been approved statistically (e.g., adult/juvenile-ratios, carapace/valve ratios). To do this, an actualistic investigation of the ostracod fauna and its taphonomy was carried out in Lake Stechlin, NE Germany.

Lake Stechlin is an almost 70 m deep, slightly eutrophic, groundwater dominated lake without any other inflows. Due to the operation of a nuclear power plant from 1955-1990 on the west shore, the lake environment has been thoroughly monitored since the 1960's, and it is therefore an excellent location for testing the analysis of ostracod records.

The modern ostracod fauna and distribution was analysed at several localities, to investigate potential differences at hydrogeological factors, anthropogenic impacts (trampling, boat landing stages, fish farms) and climatic conditions. Species occurrences and distributions were analysed for each locality, as well as abundances of species, adults and juveniles, and carapaces and single valves.

Preliminary results show that the depth distribution of adult/juvenile valves and carapace/single valves in a depth transect may only to some degree follow the expected trends in the particular lake environment. Factors such as macrophyte coverage, substrate type, shore line morphology and fish activity significantly affect the distribution of ostracods in the littoral zone, and make these proxies more difficult to interpret. Further, oxygen deficiency and carbonate dissolution in depths of ca. 11 m in the lake lead to absence of ostracods in the deep lake sediments and are another important detriment for ostracod proxies.

Abundances and assemblages vary strongly in the human impacted areas, e.g., showing high occurrences of *Cypridopsis vidua* at a fish farm, high frequencies of *Darwinula stevensonii* and *Limnocythere inopinata* at the landing stages of a boat rental, and lower diversity at the beach site compared to an undisturbed locality. Although these differences may be significant, they underline the necessity for samples for comparison from other areas, as the fauna in human affected areas may look natural.

The measurement of open apices of lower dentition as ontogenetic indicator for Pleistocene hyenas

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The study of age at death can be used to investigate modes of accumulation of fossil assemblages, including predation and the behaviour of ancient non-human and human populations. In Palaeontology, the most common analyses to estimate age are dental wear, tooth replacement or dental annuli count. However, these have some limitations because they may be affected by taphonomic biases or variation in between individuals. In physic anthropology, age estimation in humans is commonly assessed by dental development due to it is less affected by these processes. One of the most widely used methods is based on obtaining growth indices by measuring the opening of root apices in the permanent dentition. The main objective of this study is to develop a quantitative methodology for estimating age at death in Pleistocene hyenas centred on dental development. We applied X-rays on mandibles and isolated teeth corresponding to several Pleistocene sites such as Galería de la Estatuas and Galería Baja (Sierra de Atapuerca, Burgos, Spain), Cueva del Camino (Pinilla del Valle, Madrid, Spain) and Terrasses de la Riera del Canyars (Gavà, Barcelona, Spain). The radiographs were used to calculate growth indices in dental elements. The results show that this method is accurate for classifying hyena individuals through developing permanent teeth. The teeth were compiled in 2 categories for juveniles, one for sub-adults, one for adults and one for olds. Furthermore, these categories are associated with important milestones in the behaviour of individuals. The application of this method helps to the classification of isolated teeth, the most common element found in hyena assemblages, resulting in more precise mortality profiles.

Morphological study of Canis mosbachensis mandibles from Early and Middle Pleistocene European localities

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The origin of *Canis lupus* Linnaeus, 1758 probably took place in the Middle Pleistocene of Beringia and it dispersed into Europe during the late Middle Pleistocene. *Canis mosbachensis* Söergel, 1925 is a small wolf which is frequently found in Eurasian early Middle Pleistocene sites, although it is already known in the Epivillafranchian, at about 1 Ma ago. Although the Mosbach wolf is considered the ancestor of *Canis lupus* , its phylogenetic position is still subject to debate, and different classifications are suggested: as a species, subspecies of *C. lupus* or subspecies of *C. etruscus*. Considering the taxonomical problems on the lineage of this canid, more analysis are necessary to understand which is the more useful anatomical information that allow us to discriminate between the different species.
Mandibles are complex biological forms with diet-related adaptations that respond quickly to selective pressures. This work aims to analyze mandibular features of *Canis mosbachensis* remains from Vöigstedt and Untermaßfeld (Thuringia, Germany) as well as from Trinchera Dolina (Sierra de Atapuerca, Spain) sites. Here, we provide a preliminary morphological and biometrical analysis to discriminate *C. mosbachensis* from modern Iberian wolves (*Canis lupus signatus*) that allow us differentiating and characterize them in descriptive visual and numeric terms. The carnassial (M_1) and the P_4 are two diagnostic characters to distinguish between both. We used 2D Geometric Morphometry (GM) techniques for a better understanding on the mandibular variation on *Canis* evolutionary processes. This method allows us a better observation of shape changes, trough visual representations of morphological variation.
The fossil remains from Trinchera Dolina and Untermaßfeld are almost complete, however, the mandibles from Vöigstedt are scanty and fragmentary. We have initially studied the complete specimens to subsequently focus on the fragmentary remains with special attention to the P_4 and M_1.

Important findings from the TephroMed project II: The glass geochemistry of key visible tephra layers from Lake Van, eastern Anatolia

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The lake sediments of Lake Van, eastern Anatolia, are an important archive of past environmental and climatic conditions. Located in the eastern Mediterranean region, the lake is critically located between the humid Mediterranean climate and the Saharo-Arabian desert belt. Previous investigations on the record have shown major shifts in precipitation regimes throughout the last glacial to glacial period (130-30kya). The sediment core also contains visible tephra (volcanic) layers, a record of past eruptions from the volcanoes located very close to the lake. Two of which, Nemrut and Süphan, are known to have been extensively active throughout this time period. Dating of this archive has been undertaken through radiocarbon, ^{10}Be palaeomagnetism, ^{40}Ar/^{39}Ar on certain tephra layers (via proximal deposits), and wiggle matching. However, problems of large dating uncertainties and lack of independent dating has prevented insight into regional climatic (a)synchronies, particular between other palaeoclimatic records (e.g. The Dead Sea, Israel).
Here we present new single glass shard chemistry for fourteen important visible tephra layers from the ICDP PALEOVAN Ahlat Ridge (AR) record, part of the TephroMed project. These fourteen layers were chosen due to being stratigraphically positioned at major climatic transitions during the time period investigated. Extensive major and minor element data has allowed each volcanic layer to be geochemically characterised. Additional chemical information is provided with trace elements (LA-ICP-MS) as well as glass shard morphology for the fourteen layers. This new data provides important information for eruptions from Nemrut and Süphan (and other proximal volcanoes). Crucially, direct geochemical correlations between tephra layers found in distal palaeoenvironmental records (The Dead Sea) and archaeological archives in the region can now be made confidently made with Lake Van. This provides insight into the timing of major regional environmental and climatic shifts as well as with human occupation and cultural changes in the region.

Insights for restoration: Reconstructing the long-term responses and resilience of vegetation, hydrology and peat conditions to fire events in a tropical peatland in Central Kalimantan.

Ms. Khairun Ramdzan [1]

1. *University of Queensland*

Fire events in tropical peatlands are often related to dry peat conditions associated with climate variability (drought) and anthropogenic-driven ecosystem degradation. However, drought is not the only driver to long-term fire events and peatland ecosystem changes. This study used palaeoecological and geochemical proxies to investigate the long-term drivers in fire severity (FS) and the associated responses of the peatland ecosystems in Central Kalimantan, Indonesia. The results showed FS has increased from ~2300 cal. yr BP to present, and possible drivers include changes in sea level, increased frequency of El Niño events, increased biomass, and anthropogenically-driven ecosystem degradation. In response, the vegetation composition changed from a mix of peat swamp forest (PSF) and open vegetation (OV) during the late Holocene (2284 to 1129 cal. yr BP), to predominantly PSF from 1128 to 375 cal. yr BP, dry lowland mixed with swamp forest (LMS) and open vegetation (OV) from 374 to 135 cal. yr BP, and predominantly OV and FSF from 134 to -62 cal. yr BP. The drivers of the vegetation turnover were hydrological conditions and the fertilising effect from the combustion of organic matter (i.e. N release) during low FS, while the responses of vegetation turnover affect the accumulation of recalcitrant organic matter in peat. The resilience of the peatland ecosystems over longer-term timeframes provided the following restoration insights: 1) PSF species (i.e. *Eurya* and *Ilex*) had FS tolerances of up to ~23 $mm^2cm^{-3}yr^{-1}$ while LMS and OV species had lower FS thresholds of ~13 $mm^2cm^{-3}yr^{-1}$; 2) PSF expanded during periods of wet conditions and higher peat nutrients (i.e. TN- enriched from low FS); and 3) Future revegetation in the region can focus on taxa such as Araceae, Restionaceae, *Myriophyllum*, and *Ficus* as they were historically able to thrive in present baseline conditions of high FS and dry hydrological conditions.

Seasonal climate signals and temperature changes recorded by oxygen isotopes in the shells of Anularya mansuyi

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The oxygen isotopic composition of carbonate in mollusk shell is closely related to the surrounding water environment and become an important archive for reconstructing paleoclimate. *Anularya mansuyi* is a viviparid freshwater snail genus endemic to the lakes of Central Yunnan and has large size. It is widely distributed in the Quaternary lakeshore terrace in Central Yunnan. However, it is still unclear whether the oxygen isotope of its shell can be used to reconstruct the regional seasonal climate signal. In this study, the living shell of *Anularya mansuyi* in Qilu Lake was collected and sampled continuously along the spiral growth direction of the shell to test the shell $\delta^{18}O$ value, the relationship among the shell $\delta^{18}O$ and lake water temperature and lake water $\delta^{18}O$ is analyzed and discussed. The results show that (1) The oxygen isotope in the shell of *Anularya mansuyi* along the growth direction has significant seasonal fluctuation characteristics. (2) The oxygen isotope characteristics of shell carbonate shows that shell was precipitated under the condition of equilibrium with lake water, $\delta^{18}O$ value of shells is closely related to lake temperature and water$\delta^{18}O$. (3) The fluctuation of $\delta^{18}O$ values in modern *Anularya mansuyi* shell in Qilu Lake are mainly controlled by the seasonal change of temperature. With the measured $\delta^{18}Ow$ value, regional seasonal lake water temperature change can be reliably reconstructed based on shell $\delta^{18}O$ value, the temperature reconstructed by $\delta^{18}Ow$ value of summer lake water is more consistent with the regional atmospheric temperature.

A chrono-ecological framework for the Middle Stone Age and Late Stone Age of Northwest Africa

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In Northwest Africa, the distribution of Middle Stone Age (MSA) and Late Stone Age (LSA) archaeological sites spans an extensive area from Morocco to Libya, raising questions about the spatial and temporal relationship between distant sites. MSA/LSA sites include assemblages attributed to several taxonomic units - Aterian/Mousterian/Dabban/Iberomaurusian - defined by their lithic technology and typology and the presence or absence of diagnostic types in the archaeological assemblages. Technological variability within each taxonomic unit is often defined in relation to geographical and ecological factors. This task is complicated because of numerous biases (taphonomic, methodological, historical), however, making comparative analyses difficult. In this paper, we adopt a macroscale approach to the MSA and LSA. We pay special attention to the chronological evidence from individual sites and map their spatial and temporal distribution across Northwest Africa. Our goal is to establish an updated dataset of archaeological sites; assess the validity of published dates and model the pattern of human occupation diachronically by Marine Isotopic Stages. We then compare site distributions by timeframe to available landscape reconstructions based on ecological proxies and climate model outputs. This approach allows us to explore the role of climactically driven environment change as a driver of broad cultural processes such as technical change and human persistence in North Africa.

Comparing Neanderthal and Homo sapiens subsistence behaviours at Riparo Bombrini (Liguria, Italy)

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Located in the Balzi Rossi Paleolithic site complex, Riparo Bombrini documents one of the latest Mousterian occupations in Liguria (Italy), along with early Protoaurignacian occupations. Previous studies on the late Mousterian (MS) and Protoaurignacian (A1, A2) levels have revealed distinct mobility and technological organizations associated with changing paleoenvironment signatures. This makes Bombrini a key site to document the subsistence adaptations and human-environment interactions of the last Neanderthals and the subsequent arrival of modern humans in Western Europe.

We present the results of a complete ZooMS-informed zooarchaeological and taphonomic analysis conducted on levels MS, A1 and A2 at Bombrini, which provide the first high-resolution study of human subsistence during the Middle-Upper Paleolithic transition (43-36 ky cal BP) in the Liguro-Provençal arc region. These data allow us to test for the possible existence of inter-population differences in behaviour and adaptation in the context of rapid climate change on the European continent.

Palaeotempestology: understanding coastal flood mechanisms in Middle Lake, Alabama, USA

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Hurricanes are one of world's most deadly and destructive natural hazards. It has been suggested the frequency and the intensity of hurricanes are increasing in recent years. As instrumental data of hurricanes only extend back to around 170 years ago, it is essential to analyse the past to aid in future predictions. Palaeotempestology is a relatively new field of study which involves analysing a series of physical, chemical and biological proxies to identify hurricane occurrence and intensity in the past. This study examines hurricane occurrence throughout the Holocene from Middle Lake, Alabama, U.S.A. Two lake sediment cores were extracted from Middle Lake in May 2018. The cores were transported back to the U.K. and organic matter content, carbonate content, particle size, water content and ITRAX XRF analysis was conducted on both cores, and pollen and diatom analysis is underway. Both cores display a number of sand layers, which is furthered by declines in organic matter content and increases in particle size. Therefore, it is hypothesised that these sand layers are hurricane events throughout the Holocene. However, it is unclear whether the flooding associated with the hurricane events is due to storm surges, or terrestrial flooding from high rainfall. The use of non-destructive XRF core scanners in the identification of hurricane events and the nature of the flooding has been especially useful to confirm this hypothesis. This study analyses several ratios to analyse hurricane occurrence throughout the core and displays that an increase in the ratio Cl/Br is a good indication of hurricane presence with storm surges being the flooding mechanism. However, there is not a consistent pattern, and so the pollen and diatom analyses will confirm the origin of the flood deposits further. Both cores also show a significant shift throughout the core from a more marine dominated catchment source to a terrestrial. Change within the core marks a shift from a lagoonal area to a fresh-water lake. These multi-proxy analyses will further our understanding of the lake ontology and coastal flooding events.

Biofossils in borehole unravel tsunamis caused by submarine volcanic eruptions

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It is important to assess geologic hazards associated with tsunamis on the east coast of the Korean Peninsula because of nuclear power complexes, populated cities, active faults, and volcanos under the East Sea. Although tsunamis in the east coast areas were reported in historical documents, there have been no studies detecting the geological record of tsunami sediments. Here we first show three tsunami events from core samples of the lagoon. In the bacterial diversity analysis, the *Sulfurimonadaceae* known to inhabit mainly hydrothermal vents characteristically distributed only at about 0.3–2.5 ka (Event III), 6.5–7.8 ka (Event II), and 8.3–8.8 ka (Event I). The *Dictyocha byronalis*, a pelagic species, also reported in hydrothermal vents is dominant around Event I. These paleo-archive results are supported by the Fe/S ratio in the coreXRF data to confirm the Fe fluctuation trend related to volcanism. Coincidentally, Event I coincides with the volcanic activity period of Ulleung Island located in the East Sea, suggesting volcanic activity occurred on Ulleung Island and its surrounding seabed for 8.3–8.8 ka, which caused a tsunami. In addition, the rest of the periods can be used as evidence to reveal the timing of the submarine volcanic activity around Ulleung Island.

Application of sedimentary ancient DNA to 1755 Lisbon tsunami and palaeostorm deposits in Martinhal, southern Portugal

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One of the significant problems in coastal geology is differentiating between tsunami and storm deposits. So far, there is no unique set of features applicable globally to identify these deposits. Recently a promising novel technique applying ancient sedimentary DNA was suggested as a potential key to distinguishing palaeostorms and tsunamis. Thus, the present study aimed to use the palaegenomic approach for the 1755 Lisbon tsunami and younger palaeostorm deposits from the same coastal setting of the seasonal coastal lagoon in Martinhal, southern Portugal. We performed an analysis based on a specific marker for foraminifera (18S 37f) and a universal marker for eukaryotes (18S V9) in 96 samples taken from event deposits, beach, dune, shallow seabed, and freshwater stream sediments. We found that the sedimentary DNA was preserved in all the samples. While, the DNA of marine organisms was preserved in samples of modern marine sediments, the 1755 Lisbon tsunami, and several younger storm deposits. Our results confirmed the usability of metabarcoding in coastal geology. They demonstrated that ancient DNA might be preserved in harsh and unstable conditions of the temporarily flooded lagoon in the warm and arid climate in southern Europe. Thanks to the presence of tsunami and storm deposits in the same location, the results provided ground for further discussion on the advantages and limitations of metabarcoding in interpreting the coastal sedimentary record.

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A Quantified Historical Data Framework (QHDF) for reconstructing historical storms and tsunamis from archival records

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Risk assessments for coastal hazards including tsunamis or storm surges are often based on short-term instrumental records that in almost all cases fail to reflect the full range or magnitude of possible events. As such methods for accurately assessing natural hazard recurrence are becoming increasingly important as clearly such short records are inadequate for determining the natural variability of a hazard at multi-decadal timescales. While it is well known that the historical record is fragmentary, incomplete and limited in spatial balance, the historical record does provide a key link between instrumental datasets and the prehistoric record that allows for the detailed reconstruction of past events. Here, using a method developed for the study of 1921 cyclone in Western Australia we present a Quantified Historical Data Framework (QHDF) that provides a method to assess the quality of the historical information. The QHDF examines historical accounts using a five-dimensional assessment along axes of 'proximity', 'immediacy', 'accuracy', 'impartiality' and 'provenance' that can either be given equal weighting or weighted in terms of importance. The successful reconstruction of historical events is underpinned by the quality of the historical data. In this example the historical data allowed the reconstruction of a historical cyclone that implies that the event was much bigger than previously thought.

A comparison of instrumental and geologic records of storm activity in northern New Jersey, USA: Implications for extreme sea level recurrence intervals

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Determining the recurrence interval for overwash events requires a robust record of extreme storm activity. Geologic records of extreme overwash events can extend the record of landfalling storm activity beyond short instrumental records. However, the completeness of these geologic records is currently not well understood. Moreover, developing these geologic records can be difficult near urban centers, where the environments in which such records are found are often disturbed by anthropogenic activities.

Here, we develop a geologic record of overwash events from a salt marsh in Cheesequake State Park in northern New Jersey, which is adjacent to New York City that was impacted by Hurricane Sandy in 2012. We infer eight deposits within the marsh to extreme overwash events from storms. The overwash deposits are identifiable in stratigraphy by their fan-shaped morphology across the marsh and coarser mean grain size (2.7 ± 0.4 φ) compared to the salt marsh sediments (5.1 ± 1.2 φ) in which the overwash deposits are embedded. Age-depth modeling based on modern chronohorizons (bulk Pb, ^{206}Pb:^{207}Pb, ^{137}Cs, and pollen) and radiocarbon dates provides age constraints for each of the overwash deposits. The youngest of the deposits is attributed to Hurricane Sandy, while the oldest deposit is estimated to have originated from an event that made landfall between 1584 and 1658 CE (2σ).

We compare the last ~100 years of the Cheesequake geologic record with extreme sea-level events captured by nearby Sandy Hook and Battery tide gauges. Eight and ten extreme water level events above the 10 % probability of annual exceedance (AEP) level are recorded at the Sandy Hook and Battery tide gauges, respectively, and are attributed to extreme storm events. Of these events, four were also captured by the geologic record at Cheesequake. Thus, we find the Cheesequake geologic record has a 40 to 50 % preservation rate of extreme sea-level events above the estimated 10 % AEP level calculated from the tide gauge records. This implies estimates for the recurrence interval of extreme sea-level events from the geologic record would underestimate the true number of extreme events without consideration of this preservation bias.

Varying seasonal patterns of NE Atlantic storminess inferred from a 1500-years sediment record on the Shetland Islands (UK)

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The coasts of northwestern Europe are exposed to severe storm surges with the potential for high socio-economic losses. Therefore, high-resolution records of past storminess in the North Atlantic are needed to find answers to key questions such as (i) has storm activity increased over the last decades? and (ii) what risks may arise from storm surges in the future? The most destructive storms passing over Europe originate in the North Atlantic. Therefore, the Shetland Islands primely located in the northeast Atlantic serve as a window to the past frequency and intensity of storms. This study aims to reconstruct storm-induced overwash processes in lacustrine sediment cores from the coastal freshwater lake Flugarth. The variability of storm overwash is revealed by thin coastal sand layers serving as a contrast to the dark, organic-rich peat.

This multi-proxy study uses approaches including both sedimentological (grain size) and geochemical (XRF, TOC) data, and applies multivariate statistical analyses to determine the origin of the sand and peat layers within the sediment core. The resulting age-depth model is based on Bayesian AMS-^{14}C and ^{137}Cs data. Icelandic cryptotephra analyses and re-analysis of historical data were used to further calibrate the sedimentary record.

The results of our XRF Si/Ti ratio and the unimodal grain-size distribution clearly show that the sand layers originated from the beach. Phases of higher storminess with a prevailing northwesterly origin were documented between: 980–1050, 1150–1300, 1450–1550, 1820–1900 and 1950–2000 AD. These documented periods correlate with a positive North Atlantic Oscillation (NAO) mode and an increased subtropical water inflow into the northeast Atlantic. During these warm phases of the last 1500 years, storms occurred mostly in winter and their track shifted towards the northeast Atlantic. However, during the Little Ice Age (LIA, ca. 1400–1850 AD) high-intensity storms were predominantly from other directions than north(west), and a southward shift of storm tracks dominated along with storms occurring mostly in autumn and spring. These findings support IPCC forecasts of future storm track changes and an expected increase in winter storminess in the northern North Sea.

Impact on the German North Sea coast by the Storegga slide tsunami around 8150 cal BP

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The Storegga slide tsunami (SST) at ca. 8100 ± 100-250 cal BP is known to be the largest tsunami that affected the North Sea during the entire Holocene. Geological traces of tsunami landfall were discovered along the coasts of Norway, Scotland, England, Denmark, the Faroes and Shetland Islands. So far, the German North Sea coast has been considered as being well protected due to the wide continental shelf and predominant shallow water depths, both assumed to dissipate tsunami wave energy significantly, thus hindering SST propagation dynamics. The objectives of our study were to clarify if the SST reached the German Bight and if corresponding sediment markers can be found. Our research was based on a 20 m long sediment core (GAR 1A) recovered from Eiderstedt Peninsula near Garding in North Frisia. High-resolution Direct Push sensing data and results of multi-proxy analyses of the sediment material were used to reconstruct palaeoenvironmental as well as palaeogeographical conditions.

We identified a high-energy event layer with sedimentological (e.g. erosional unconformity, rip-up clasts, fining upward), microfaunal (e.g. strongly mixed foraminiferal assemblage) and other features (e.g. upward increase of organic matter) typical of tsunami influence and identical in age with the SST. The event layer was deposited at or maximum ca. 1-1.5 m below the local contemporary relative sea level and minimum 40 km inland from the coastline within the palaeo-Eider estuarine system beyond the reach of storm surges. Tsunami facies and geochronological data correspond well with SST signatures identified on the nearby island of Rømø. SST deposits identified at Garding represent the southernmost proof of this event in the southern North Sea. They give evidence, for the first time, of high-energy tsunami landfall along the German North Sea coast and tsunami impact related to the Storegga slide.

It is suggested that the SST was not essentially weakened across the shallow continental shelf of the North Sea, but largely intruded the estuarine systems in North Frisia by tens of kilometres inland.

The sedimentary imprint of the ~8.1ka Storegga tsunami in Northumberland, northern England

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Coastal sites in Scotland and Norway provide extensive evidence for the occurrence, timing and impacts of the Storegga tsunami, the largest tsunami to have struck North Sea coastlines during the Holocene. Sedimentary evidence from English shores has been less widely reported, likely due to erosion and submergence of the deposit by subsequent relative sea-level rise. Nevertheless, in northern Northumberland, the comparative stability of sea levels over the mid and late Holocene offers the potential for enhanced preservation of Storegga tsunami deposits. Here, we provide a detailed characterisation of a laterally extensive sand sheet at Broomhouse, approximately 10 km south of Berwick and 2 km inland from the modern coastline. Sea-level research at the site in the late 1990s identified that this layer abruptly interrupted supratidal deposits. Based on an extensive new stratigraphic survey, we trace the layer to a maximum elevation of more than 6.8 m above our estimate of contemporaneous sea level. Radiocarbon dating strongly supports the association of the deposit with the Storegga tsunami and we identify a range of sedimentological characteristics that further corroborate the origin of the layer. We use a multi-resolution finite element numerical model to explore the implications of the elevation, extent, and grain size of the Broomhouse deposit for understanding the characteristics of the incoming wave and aspects of the inundation of the coast of northeast England.

New sedimentary evidence for the ~1500 BP tsunami on the Shetland Islands

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Tsunami deposits are required to assess the long-term hazard of tsunamis, in particular in regions with a short and fragmented historical record. In the North Sea region, historical evidence of tsunamis is scarce. However, the Shetland Islands are an exception, as they provide abundant sedimentary evidence of the Storegga tsunami 8200 BP, and more fragmented evidence of younger events ~5500 and ~1500 BP. Sediments of the 1500 BP tsunami have only been found in two sites so far, as thin landward fining and landward thinning sand sheets which are vertically confined by peat.

Here, we present sedimentary evidence for the ~1500 BP tsunami from the small coastal lake of Loch Flugarth, northern Mainland. Three gravity cores of up to 91 cm length were taken behind the barrier separating the lake from a marine embayment. The cores show organic-rich background deposition with many (sub)mm-scale sand layers in between, reflecting recurring storm overwash and a sediment source limited to the active beach and shallow embayment. A basal 13 cm-thick sand layer, dated to 426–787 cal yr CE based on ^{14}C-AMS and ^{137}Cs and Bayesian age-depth modelling, was found in all three cores. High-resolution grain-size analysis identified four normally graded sublayers with inversely graded traction carpets in the two lower sublayers. A mud drape and mud cap cover the upper two sublayers, which also contain a rip-up clast. Endmember modelling of grain-size distributions shows a difference between the basal sand layer and the thin storm layers, which are coarser and better sorted. Principal component analysis of XRF core scanning data also distinguishes both sand units, mostly driven by Zr and Fe in the basal sand. This, in combination with increased magnetic susceptibility, may be related to higher heavy mineral content reflecting a deeper additional sediment source for the tsunami deposit. The source of the ~1500 BP tsunami is unknown, but it is estimated to be of local origin as associated deposits have not been found outside the Shetlands. The size of the tsunami is estimated to be smaller than the Storegga tsunami, which affected most of the North Sea basin.

Geomorphological features of storm-induced depositional landforms in the SE Baltic Sea coastal zone

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Storm surges influence sediment distribution along the sandy barriers. If the water level reaches the top of the dunes, sediment is moved to the back-barrier environment through breaches, forming washovers. These landforms are the direct result of contemporary storm surge events. In favourable conditions, sediments related to storm events are also preserved in the sedimentary record and become a valuable archive of past coastal floods. Thus, information on washover's shape, internal structure and properties of deposits may help better understand processes that lead to their formation and preservation in the sedimentary record.

The Southeastern Baltic Sea coastal zone (of a semi-enclosed, nearly tideless water reservoir) was subjected to the analysis of washover features. The fieldwork comprised hydroacoustic surveys using a Multibeam Echosounder (MBES) and Unmanned Aerial Vehicle (UAV) equipped with a photogrammetric camera, a laser scanner, and a multispectral camera. Surface data on morphology was supported by Ground Penetrating Radar (GPR) and surface sampling to obtain information about sediments. The gathered dataset was processed in QINSy, Pix4DMapper and CHCNV software. Secondary feature datasets were generated using ArcGIS, Matlab, R, and eCognition software.

The preliminary results allow us to compare dimensions of washovers formed at the coasts that differ in the basic geomorphological setting. In general, the slope of the nearshore zone, the height of dunes, surface sediment distribution and beach morphology influence the efficiency of sediment transfer to the back-barrier environment. The results also indicated incoherence of surface sediments traceable with a multispectral camera and possible application of this sensor to study surface sediment dynamics in the coastal zone.

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An unexpected record of the 1922 Atacama tsunami. Historical and micropaleontological evidence in Carrizal Bajo (southern Atacama Desert)

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On November 10th, 1922, at 23h 53m Chilean time, the Mw8.6 Atacama earthquake shook generating a highly destructive transoceanic tsunami with flood depths in the coastal cities near the epicenter of 7 to 9 m. There is no historical description of the tsunami arrival time to Carrizal Bajo (Atacama, Chile) but the chronicles report that two waves hit the port a few minutes later. The first wave razed the docks, the ships, the port offices as well as the train terminal station and workshop. The second one destroyed several buildings, the power station and residential houses reaching a flood height of 6 m above the mean sea level. The waves penetrated inland between 1.5 and 2 km washing away a locomotive and its train cars, tearing the electric engines off their foundations and scattering and burying the petrol barrels a kilometer away from the installation.
Inside of what we have identified as the half-buried locomotive boiler, located more than 600 m from the present coastline, a moderately sorted, medium to fine sand deposit appear. It is partially cemented by iron oxides and together with this rust its analysis has revealed the presence of foundry slags, metallic spherulites and coal that record the destruction and landward transport of the railway and metallurgic infrastructures originally located near the port. Its micropaleontological study has shown very common marine specimens such as siliceous sponge spicules, echinoderm radioles, bony fish teeth, benthic foraminifera (e.g., *Buccella peruviana*, *Quinqueloculina seminula*, *Cibicides ornatus*) and ostracods (e.g., *Xestoleberis chilensis, Cyprideis beaconensis*) with some fragments of calcareous nannoplankton (e.g., *Thoracosphaera*). Occasionally, freshwater organisms appear as charophyte girogonites, gastropods (*Heleobia copiapoensis*) and amoebas (Arcellinidae) with some brackish ostracods (e.g., *Cyprideis beaconensis*). Altogether, the locomotive and the sandy sediment within represent an exceptional archeological-historical-geological record of the last large tsunami recorded in the southern edge of the Atacama Desert. The strong onshore flow was able to displace tens of meters an iron locomotive ant its railcars, accompanied by high volume of sandy sediments eroded from the subtidal, intertidal and the wetland zones during the marine flooding.

The morpho-sedimentary record of the 1922 Atacama tsunami in the Copiapó coastal wetland (Southern Atacama Desert)

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The November 10th 1922 earthquake (Mw~8.5–8.6) is considered to be the second largest seismic event occurred in Chile during the 20th century after the 1960 Valdivia earthquake (Mw 9.5). The earthquake had a rupture close to 500 km long and it was felt in most of Chile and South America. It generated a destructive transoceanic tsunami with maximum wave heights of 7 to 9 m close to the epicenter that not only caused damages along the Chilean coast but also hit Perú, Hawaii, Samoa Islands, Taiwan, and Japan. Despite its magnitude, the geological record of this recent event is poorly studied, on the one hand, because of the low preservation potential of the tsunami deposits on arid coasts and on the other, due to the irregular and steep configuration of the southern Atacama Desert coast.

In this work we present the first evidence of the marine flood generated by this tsunami in the Copiapó coastal wetland. We focus on its northern sector where a narrow strip of wetlands and small coastal lagoons occur parallel to a foredune (heights >2.5 m) and beach systems. The geomorphological analysis of the area has shown several breaches of the littoral dune ridge and the formation of washover fans over older saltwork structures. The excavation of trenches has revealed a sandy layer 2 to 11 cm thick at 20 cm below the surface. It is formed by massive and well sorted fine sands with erosive base interbedded with argilite, peat and sandy shale deposits, as well as paleosoils interpreted as flood and arid marsh facies. In addition, a few specimens of sponge spicules, fragments of ostracods, diatoms, and marine benthic foraminifera have appeared in this tsunami deposit. Channelized return flow incised the initial breach opening and formed the small lagoons, with a V-shape oriented toward the sea, that are now disconnected from the beach. These last forms constitute the only obvious evidence that have been preserved in the landscape of the 1922 tsunami, although they continue acting as preferred discharge zones toward the sea during extreme fluvial floods in recent times.

Portuguese offshore tsunami deposits - a hydroacoustic survey

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The 1755 CE Lisbon tsunami caused widespread destruction along the Portuguese, Spanish and Moroccan coasts. In Portugal, this event's onshore record is particularly well-studied. The offshore record, on the other hand, is until now sparse and not well understood. RV METEOR cruise M152 sailed to study offshore imprints of the 1755 CE Lisbon tsunami and possible preceding events on the southwestern Algarve continental shelf, southern Portugal. Deposits of the 1755 CE Lisbon tsunami and of an older event dated to around 3400 years BP, were identified in the sediment cores. Especially the deposits of the the latter event are represented by an extraordinarily strong reflector in the recorded sub-bottom profiles.

Here, we present an interpretation of sub-bottom and seismic profiles recorded during cruise M152 and one additional cruise which extended the original profiles into shallower waters. During cruise M152, an Atlas Parasound echo-sounder was used, while the additional cruise included a sub-bottom survey with a parametric echo-sounder and 2D single-channel seismics. The Late Quaternary sedimentary record of the southwestern Algarve shelf was in the focus. Most of the study area is characterized by rough erosional seafloor and exposures of bedrock with only thin sedimentary cover. In some areas, one or more strong reflectors were recorded and, where possible, correlated to the stratigraphy of the sediment cores. Mapping of the strong reflector related to the 3400 years BP event revealed its lateral distribution on the shelf. Only the strong compositional contrast between the event layer and the surrounding sediments in water depths between 30-70 m is capable of producing an extraordinarily strong reflector. But in the cores, deposits of the 3400 years BP event extend further until around 90 m water depth. In the deeper cores, a thinning and fining trend of the event layer is observed.

Our study demonstrates the advantages of using hydroacoustic profiling to study the Late Quaternary sediment cover of the Algarve shelf to better reveal the spatial extent of offshore tsunami deposits.

Deciphering high energy wave-induced sediment deposits using spectroscopic technics

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In the last two decades, several devastating wave-induced events such as the 2004 Indian Ocean tsunami, 2011 Tohoku tsunami and the 2018 Palu tsunami, demonstrated the need for reliable information on the magnitude and recurrence interval of such events. Sediment archives are a major source of data on extreme palaeoenvironmental events. However, despite a considerable progress in tsunami research, the multi-proxy characterization of tsunami deposits for reliable identification of changes in sediment provenance remains a major scientific challenge because it provides insights into source materials and their environmental context at the time of the event. The increasing reliance of such studies and the need for robust identification and characterization of sediment deposits, motivated the research of reliable, time-saving analytical tools and procedures. Here we compare four rapid (1sec – 2min), non-destructive and accurate spectroscopic technics for semi-quantitative mineralogical, geochemical and bio-chemical characterization of sediments. Portable visible spectrocolorimetry, benchtop mid infrared spectroscopy (Fourier Transform attenuated total reflectance and diffuse reflectance) and portable X-Ray fluorescence were used to characterize and discriminate high energy wave-induced sediment deposits. Sediment deposits were collected from 7 ka year record of high-energy deposits recorded in a coastal cave along the north-western coast of Sumatra (Indonesia). Compared to more conventional technics such as atomic absorption spectroscopy, inductive coupled plasma mass spectroscopy, scanning electron microscopy, visible (VIS) and infrared spectroscopy (MIR) analytical approaches used in this study are faster and less costly. Compared to conventional X-Ray diffraction, MIR spectroscopy is not subject to analytical biases introduced by the differential settling or preferred orientations of minerals, allows identifications of amorphous phases and only requires small samples (> 20 mg) and brief measurement times (~1 min). Due to its wide range of wavenumbers (VIS, 400-700 nm; MIR, 4000-450 cm^{-1}), spectra are highly discriminant and allow strong source to sink determination using multivariate statistics and machine learning. The results show strong discrimination between the subsequent high-energy events, suggesting significant environmental differences of source materials and their palaeoenvironmental (inland, offshore) and geomorphological context (lagoon-mangrove, dune, beach etc.). The advantages, the limits and the wider significance of the methods are discussed.

Tsunami potential source in the eastern Sea of Marmara (NW Turkey), along the North Anatolian Fault system

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Tsunamis could be generated by direct displacement of the seafloor due to a fast motion during an earthquake, or by mass failure as a consequence of earthquake shaking or other natural/anthropogenic causes, resulting in so-called “landslide tsunamis”. Although in different proportions, both mechanisms can play a role during most tsunami events, particularly those generated close to continental shelves.
The Sea of Marmara is particularly prone to landslide tsunami hazards for multiple reasons. First, it experiences large-magnitude, relatively shallow earthquakes, along active segments of the North Anatolian Fault (NAF) system, one of the most seismogenic structures on Earth. Second, it is bounded by steep fast-subsiding slopes, favoring relatively thick and unstable sedimentary sequences piling up over natural sliding planes. Third, it has been affected by dramatic water-level changes during the Pleistocene/Holocene transition, and most probably during previous glacial/interglacial cycles, primarily controlled by the natural Dardanelles and Bosphorus sills primarily controlled by the natural Dardanelles and Bosphorus sills. This peculiar physiographic setting could have favored catastrophic inundations, mega-turbidites, and slope instability during eustatic transitions and/or variations of hydrostatic pressure conditions. In the Sea of Marmara, gravitative failures could also be enhanced by the presence of geological fluids in the sediments.

Several oceanographic expeditions carried out in the Sea of Marmara after the *Mw*=7.6, 1999 İzmit earthquake highlighted the effects of gravitative instability and landslides, shown by slumping scars, actively gliding masses, or chaotic deposits in the sediments. In this general framework, high-resolution marine geophysical data led us to recognize a sizeable potential landslide mass in the Çınarcık Basin (eastern Sea of Marmara), close to the entrance of the Gulf of İzmit, which we called the South Çınarcık Landslide (SCL). This submarine landslide body could represent a potential hazard for the Sea of Marmara coasts, particularly in the NE sector between the Armutlu Peninsula and Istanbul. Our work attempts to define possible scenarios in case of a massive failure of this body due to future earthquakes or other causes and could be used as an example of a multidisciplinary study towards understanding and mitigation of landslide tsunami risk in other regions.

Storm or tsunami, that is the question - the sedimentary record of the 1755 Lisbon tsunami and palaeostorms in Martinhal (southern Portugal) revisited

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One of the significant problems in coastal geology is differentiating between tsunami and storm deposits. Addressing this issue, studies comparing characteristics of event layers formed by various mechanisms on the same coast are particularly important, because many local factors (topography, bathymetry, sediment sources, climate, etc.) may affect sediment deposition from extreme coastal flooding. Such an approach was previously used by Kortekaas and Dawson (2007, Sedimentary Geology 200: 208–221) for a coastal lowland in Martinhal nearby Sagres in southern Portugal, where 1755 Lisbon tsunami deposits and several palaeostorm layers were documented. We have extended this previous work by multidisciplinary investigations, including detailed field mapping (DGPS based) and investigation of sedimentary records in over 70 sites, mainly in up to 90 m long trenches, providing new insight into a thus far complex stratigraphy. The sampling of the trenches was supplemented by hand coring and a collection of endmember samples from potential sediment sources: continental shelf, nearshore, beach, dune, river channels, and local soils. To reconstruct the evolution of the coastal lagoon and the nearby plain of Martinhal, the impact of catastrophic floodings (tsunami and storms), and the specific characteristics of event deposits, we applied a wide range of methods. The latter included geochronology (^{210}Pb, ^{137}Cs, and ^{14}C), sedimentology (sediment architecture, sedimentary structures, grain size analyses), geochemistry (XRF, ICP MS, LOI), mineralogy (heavy minerals, magnetic susceptibility), micropaleontology (diatoms, dinocysts, foraminifera, Tardigrada, Cladocera) and sedimentary ancient DNA. We carefully assessed the application of these proxies in the context of differentiating tsunami and storm deposits. We underline that changes in the coastal systems in time, particularly after extreme events (e.g., changes in coastal barrier height and shape), must be considered when interpreting the type and frequency of event deposits. This research was funded by the Polish National Science Centre grant No. 2020/37/B/ST10/03677 (TSUNASTORM).

Resilience of coastal peatland to the tsunami based on palaeoecological study of 1929 Grand Banks tsunami impact in Newfoundland

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Extreme marine inundations such as tsunamis and storm waves drive changes to coastal environments worldwide. Their frequency and magnitude are going to change in the future along with rising sea-level, and will significantly impact ecosystems of coastal peatlands, influencing their hydrology, structure, vegetation, microorganisms, and carbon burial rate. Despite the increasing number of studies, the specific response of coastal peatland to extreme and short-term events like a sudden increase in salinity due to extreme marine flooding, combined with delivery of sand and organics, as often caused by a tsunami, is largely unknown. The aim of this study is to determine 1) what is the response/resistance of coastal peatland to an inundation, 2) how quickly does coastal peatland recover after burial with tsunami deposits, and 3) how palaeoecological data can inform studies of peatland recovery after a tsunami. Hence, we conducted high-resolution analyzes (0.5 to 1 cm) of two peat cores from the Burin Peninsula (Newfoundland, Canada). The 210Pb and 137Cs dated cores were collected from the blanket bogs affected by the 1929 Grand Bank tsunami that can be traced in our record by thick sand layers interbedded in organic sediments. We used testate amoebae analysis to reconstruct long-term hydrological dynamics and track the changes in the community of testate amoebae, and plant macrofossils to reconstruct changes of the local vegetation. Despite a significant tsunami impact, peatland recovery occurred within the following decades and led to the development of a fully functional peatland ecosystem. The research is carried out as a part of an OPUS project (2020/37/B/ST10/02614) financed by the Polish National Science Center.

Sedimentary traces of tsunami events recorded in the Sea of Marmara during the last millennium (Kumlubent Lagoon, NW Turkey)

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The Sea of Marmara and its coastal regions are one of the few areas in the world with a thorough earthquake history. Lagoon environments that are separated from the sea by a narrow strip of sandbar can provide protection from post-depositional erosion and hence are critical coastal areas hosting traces of earthquake-related tsunami events. However, most of the coastal regions in the Marmara Region have been under rapid urbanization, and only a very few areas preserve original coastal sediment successions. This study provides the first multi-proxy sediment core analyses of a lagoon on the Marmara coast that is located in the Kumlubent coastal region in Gelibolu Peninsula, Çanakkale. Two sediment cores, retrieved from the Kumlubent lagoon were 3.40 m and 2.78 m long, respectively. The ITRAX micro-XRF scanner is used to obtain 0.2 mm-resolution radiographic images and 1 mm-resolution XRF data for the element distributions of twenty-five elements including Al, Si, P, S, Cl, Ar, K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, As, Br, Rb, Sr, Y, Zr, Ba, Ce, Pr, Pb. Further geochemical analyses including TOC, $\delta^{18}O$, and $\delta^{13}C$ in the carbonate shell material will be investigated in order to understand the past oceanographic changes in the region that could be related to the events encountered in the sediment cores. The age model will be done by using AMS ^{14}C dating together with ^{210}Pb to obtain high-resolution age data. Our results showed that gray sandy sediment deposits of the Kumlubent lagoon are intercalated with several event-type sediment deposits including the variable thickness of; brownish gravel layers of terrestrial origin, gray gravels of marine origin, layers with high contents of marine bivalves and gastropods (*e.g. Turritella communis*) of pelagic origin, and black sapropels with high organic content and liquefaction structures. Geochemical and biostratigraphic analyses pointed out strong evidence of terrestrial and pelagic events which can be related to past tsunami and earthquake events as well as flood and storm events. These event-type sedimentary units are discussed within the historical records in order to understand the timing and influence of both the tectonic and paleoceanographic history of the region.

Coastal calc-arenites as a new archive of Holocene storminess in the SW Indian Ocean

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Because of their violent nature, extreme-wave events leave a trace in the sedimentary record in the form of sediment layers, erosional surfaces or both. Identifying and dating these traces is used to gain an understanding of recurrence intervals and magnitudes of extreme-wave events over geological timescales. Unlike for the Atlantic and Pacific Oceans, there is no robust record of extreme-wave events for the SW Indian Ocean. In a recent study based on a record of shelf-hosted tempestites, it was revealed that Holocene storminess along the SE African margin was higher than previously thought (Green et al. 2022). In the context of coastal deposits, we expand this record of storminess to include coastal calc-arenites, like beachrock, that also comprise archives of extreme-wave events in the region. At Mission Rocks on the KwaZulu-Natal coastline of South Africa a narrow beach with isolated sand patches occupies low points of an otherwise continuous 3 m-thick, raised shore platform of sandy and gravelly beachrocks. Here tempestites occur as poorly sorted pebbly sandstones with erosional bases. Individual beds contain convex down shells, exotic shell content and cobble sized clasts of the underlying calcarenite layers. Based on the sedimentological facies analysis, radiocarbon dating, petrography and isotope geochemistry, we unravel the timing and magnitude of event layers along the coastlines of NE South Africa. Our work adds to a more complete understanding of marine flooding hazards for the region, to which we link to known fluctuations in the region's climatic drivers.

Applications of 210Pb and other gamma-emitting radioisotopes for studies of tsunami and storm deposits – insights from the coastal plain, lagoon, and continental shelf deposits

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Geochronology applying ^{210}Pb and ^{137}Cs is commonly used to date sediments back in time to over 100 years ago. However, these isotopes may reveal more than the age model of a sediment core. They also provide essential insights into the sediments and sedimentary processes. The present paper aims to highlight some of these opportunities (and also limitations) based on case studies from the tsunami and storm-affected environments: the coastal plain and lagoon at Martinhal (southern Portugal), the coastal plain and lakes of Newfoundland (Canada), and Andaman Sea continental shelf deposits. These sites were affected by major tsunamis (e.g., the 1755 Lisbon tsunami, the 1929 Grand Banks tsunami, and the 2004 Indian Ocean tsunami) and storms, hurricanes, and typhoons. The application of ^{210}Pb and other gamma-emitting radioisotopes helped in addressing significant problems in coastal geology, namely the identification of event deposits and tracing the impacts of tsunamis and storms on coastal ecosystems. On the examples of the new data, we presented typical activity-depth profiles for gamma emitting isotopes (e.g., ^{40}K) and excess ^{210}Pb. We highlighted the potential to assess event deposition, erosion due to extreme events, and changes in local sedimentary systems leading to changes in sediment accumulation rates. We concluded that in some cases, the change in radioactivity profile may be the key to identifying event deposits in the offshore record. Moreover, radiochemistry may provide insights into areas of sediment bypassing and sediment sinks, as well as reveal sediment provenance. The simultaneous application of the radiochemical methods along with sedimentological, geomorphological, and geochemical approaches may provide very valuable insights into the interpretation of extreme marine flooding events and their impacts. This research was funded by the Polish National Science Centre grants No. 2020/37/B/ST10/03677 (TSUNASTORM) and 2020/37/B/ST10/02614.

Coastal boulders in Cuba: implications for paleotempestological research in the Caribbean

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Boulders transported and/or moved by high-energy wave events have been the subject of research in different regions of the planet, including the Caribbean, which has historically been affected by hurricanes and tsunamis (the former more frequent than the latter). In Cuba, there are numerous areas with such boulder deposits; however, their origin (whether due to paleohurricanes or paleotsunamis, is unknown. The conditions that favor the deplacement of boulders, their different spatial distribution, size, and distance from the coast were studied and are presented here. The transport and deposition of boulders is likely the result of different factors, including the lithological characteristics of marine terraces (submerged and emerged), the presence (or absence) of coral reefs, and geomorphological factors (e.g., sea depth, underwater slope inclination, distance between the coastline and the island slope, and coastline orientation). On the south coast of Cuba, these accumulations are more common, and are characterized by blocks that are larger than elsewhere (mean volume between 5 and 50 m^3); on the north coast, the average volume has values from 1 to 5 m^3. These results are important because they are related to extreme wave events that have impacted the Cuban coastline, both in the past and in the present, and provide a new potential source of information for paleotempestological research in the region, which may help prevent hazards and disasters in the future.

Differentiating tsunami and storm deposits – application of heavy minerals analysis

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Although distinguishing tsunami and storm deposits affected by postdepositional changes may be possible by using a multi-proxy approach, their identification is often difficult because they are dependent on multiple factors and there exists no unique set of features which could be applied. One approach to distinguish these deposits is to apply heavy mineral analysis. The presence of heavy minerals (HM) has been frequently noted in tsunami and storm deposits, but they have hitherto received little attention. However, HM analyses may be useful in finding sediment provenance (e.g. marine), and trends (vertical and spatial) in HM assemblages within tsunami and storm deposits resulting from hydraulic sorting processes acting during the tsunami or storm. To test the applicability of HM analysis, modern tsunami deposits left by the 2004 Indian Ocean tsunami on Kho Khao Island, Thailand and by the 2011 Tohoku-oki tsunami on Sendai plain, Japan, were studied. The study of heavy minerals in storm sediments was tested on the southern coast of the Baltic Sea. In turn, the test area for both tsunami and storm sediments was the study of sediments in the Bay of Marthinal, on the SW coast of Portugal. The HM fraction content and mineral assemblages significantly differ between the individual case studies. The content of the fraction ranges from less than 1% in storm sediments of the southern Baltic Sea to over 30% in the sediments of the Tohoku-oki tsunami. Differentiation is also observed in the composition of HM. While the mineral assemblages of transparent HMs depend on the available source rocks, the presence and distribution of mica and opaque, particularly limonites, are a good indicator of the mode of transport. Thus, HM analysis may be a useful supplementary tool in tsunami deposit studies, however, the interpretation must always be put into the local geological context and evaluated in tandem with other proxies such as diatoms.

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In search of high energy marine deposits in coastal archaeological sites: first results from the ancient Greek-Roman town of Elea-Velia (Campania, Italy).

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The Mediterranean region is particularly rich in paleotsunami data, thanks to the availability of historical records that provided precious clues to geologists and archeologists in search for "the direct evidence of tsunamis" (e.g. sediments, morphological signatures, destruction layers). Tsunamis in the Mediterranean may originate from large earthquakes as well as active volcanoes and significant submarine landslides. Some evidence for past tsunami, associated to volcanic eruption (e.g. 79 CE Vesuvius eruption as reported by the ITED database) and related landslides of the Vesuvius, Phlegrean Fields and Ischia volcanoes, are reported in some archaeological excavation along the coastline of the Campania region highlighting significant tsunami hazard along one of the most populated coastal areas in Italy.

We report preliminary results from a multisciplinary study conducted in the Greek-Roman archeological site of Elea-Velia, located along the Cilento coast in southern Italy, carried out in the frame of the INGV-Ricerca Libera 2019 project and the scientific Memorandum of Understanding between INGV and the Paestum-Velia Archeological Park.

Recent archaeological excavations conducted in the Roman necropolis (1st-2nd century CE) and in the southern part of the town, reported a volcanoclastic deposit referable to 79 CE covered by a storm/tsunami deposit made of a thick layer of marine sands interbedded in a continental sequence.

ERT and GPR profiles, both located in the Roman Necropolis area and outside the city walls, were carried out in order to reconstruct the shallow subsoil setting and identify buried features covered by archaeological restoration. Based on geophysical outputs, ten cores were collected by means of a gasoline-powered percussion hammer equipped both with slotted and closed PVC pipe, down to the maximum depth of 6.20 m.

Preliminary results show a complex stratigraphy that points to the interplay between natural environments and human activities as far as back to the 3rd century BCE. Magnetic susceptibility on selected cores, highlight at least two volcanic ashes likely referable to 79 CE eruption. Further analyses are still in progress, aiming to characterize and date ash layers and the whole stratigraphy made by alternating of fine and coarse sediments full of pottery remnants, looking for potential tsunami deposits.

Progress and opportunities in ISROC: A Research Coordination Network targeting coastal boulder deposits

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Intertidal and supratidal coastal boulder deposits (CBD) result from extreme marine inundation on rocky shores. They are important for understanding long-term coastal wave hazards (both storm and tsunami), have potential predictive value for future events, and support assessment and planning for rocky coasts. However, there are at least two main obstacles to deeper understanding of CBD transport and applications: a lack of data on CBD worldwide, and discrepant approaches that lead to difficulties in comparing data from different sites. Building community and interaction among CBD researchers, and awareness of CBD as research targets, can help grow our knowledge and our ability to tackle these questions.

ISROC—Inundation Signatures on Rocky Coastlines—is an NSF-funded Research Coordination Network started in 2021 to define the CBD problem chain and identify research gaps by developing a broad and diverse network of researchers. The authors of this abstract are the ISROC PIs and steering group. Our goals are to extend the community of researchers to include underrepresented groups; to facilitate the development of standards and best practices for gathering and archiving CBD data; to develop cyberinfrastructure for uploading, visualizing, and analyzing data; and to train the next generation of CBD researchers. Understanding CBD and using them as a tool to reconstruct coastal inundation history and extreme climatological states is a prime example of convergence research that one discipline cannot solve. Thus, we create opportunities for cross-disciplinary collaboration and exchange. The ISROC network includes geologists, geographers, oceanographers, engineers, hydrodynamicists, geophysicists, climatologists, and paleoclimatologists. ISROC activities include meetings, student training, exchanges; sessions at major conferences in geoscience and coastal engineering; consolidation of survey/mapping approaches; and building a global database, including user-friendly, fully accessible online data archiving. Understanding past inundation and how CBD form and evolve will help quantify present-day risk and provide guidance for what to expect from future climate and sea levels.

New intensity map for the Mw7, November 19, 1912, Acambay earthquake, Mexico: a re-evaluation of the EEE's by ESI-07 scale

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The 1912 Acambay seismic event is the best documented historical crustal earthquake associated with surface rupture within the Trans-Mexican Volcanic Belt. It was accompanied by both primary and secondary environmental effects on the Acambay graben and nearby central Mexico. However, inaccuracies and contradictions in historical documents have led to different interpretations about the tectonic surface ruptures and other coseismic effects such as landslides and liquefaction. We revisited the sites first described by contemporary sources, and revised trench investigation conducted across the coseismic ruptures. This allowed us to obtain a new and more precise map of the distribution of environmental effects and ESI-07 epicentral intensity.
A detailed review of documents (historical archives, photographs, newspapers, reports), assisted by fieldwork, interviews with inhabitants, and paleoseismological studies, provided new data allowing a better characterization of the earthquake and its effects on the natural environment. The classification and re-evaluation of the primary and secondary effects led to reinterpret the macroseismic field and the intensity distribution within the graben. The ESI-07 isoseismals of maximum intensity values correlate with the location of the surface ruptures, showing that the rupture occurred A) at the northern border of the graben, in the Acambay-Tixmadejé fault; B) at the southern border, in the Pastores fault and; C) along the central fault system, involving the Temascalcingo and San Pedro faults. The above suggests that multifault rupture event scenarios, with related higher magnitudes, have to be considered on Central Mexico, a region with significant urban and infrastructural development that concentrates more than 50% of the population of the country.
This study highlights the importance of considering the EEE's in order not to underestimate the intensity values in the epicentral area, and also suggests the use of the ESI-2007 scale as an effective tool to assess seismic hazard.

The Trans-Mexican Volcanic Belt and its active faults: creation of an update database through geomorphic analysis, heavy bibliographic compilation and extrapolation of coherent values

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The Trans-Mexican Volcanic Belt is a continental volcanic arc that crosses central Mexico from the Gulf of Mexico to the Pacific Ocean. Despite being affected by different active crustal fault systems responsible for several destructive historical earthquakes, more than 50% of the Mexican population lives in this geological province, in megacities, increasing the seismic risk.

More than 600 fault segments have been mapped in the Trans-Mexican Volcanic Belt, but only 5% of these structures have been studied enough to characterize their seismogenic potential.

Several works are disponible on literature using different approaches such as structural geology, geochronology, tectonics, historical crustal seismicity, paleoseismology, geophysics and seismic hazard assessment, and could be compile to form an updated database with all the necessary parameters to incorporate faults data within seismic hazard assessment.

We present here this compilation and how we used it, extracting relevant information on the ages of rocks displaced by the activity of faults within the Trans-Mexican Volcanic Belt, slip rate, displacement speeds, height of the escarpments, among others. In addition, an extrapolation of the data found in the literature for other fault segments within the same system and with similar characteristics is proposed. For this, a geomorphic study has been performed using digital elevation models, satellite images and different types of maps in Qgis software. Key parameters for future risk analysis are established, such as the length of the fault trace, azimuth, coordinates of the extremes, proximity to large cities, as well as important or dangerous infrastructures (dams, oil pipelines, etc.). With this work, a new database is proposed where punctual information for the different segments or fault systems with potential seismogenic activity is organized and quantified. This new database will allow the incorporation of cortical fault data in seismic hazard assessment at the scale of the Trans-Mexican Volcanic Belt.

PASTORA: An example of inclusion of gender perspective in geosciences research

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The inclusion of the gender and/or sex dimension in research (IGAR) renders higher quality, more correct scientific results, and avoids adverse effects, as recommended by the Gendered Innovations Program (European Commission in collaboration with Stanford University), and by the National Science Foundation of the United States. For those research areas where human beings are not directly involved, as in Geosciences, IGAR tools suggest to explore the extent at which men and women can also be the object of research when considering potential final users of the findings, and customers, workers or citizens.

In this contribution the gender perspective in the PASTORA project is explored. The research project aims to determine the patterns of resilience and use over time of different pastures in high altitudes of the Central Pyrenees (NE Iberia) using paleoenvironmental, palynological, archaeological and modern ecology techniques. The approach is focused on the analysis of grazing impacts on mountain ecosystems from the Prehistory to assist in the design of appropriate subalpine pasture conservation policies and strategies. The gender perspective is important, firstly, in the study of the prior knowledge of ancient pastoralism practice and sexual division of labor in the past. We are aware that part of this traditional and ancestral profession has included, includes, and will include in the future, women shepherds. Also, it is proposed that recent efforts made to maintain traditional practices, interests and visions, should include women shepherds in activities or projects, with the support of society, public administrations, and scientific research. And finally, results diffusion and outreach activities are designed to reach not only local networks and stakeholders as rural women entrepreneurs, but also institutional bodies involved in reverting depopulation.

The research team of PASTORA project (whose acronym in fact means ‘women shepherd’), with an approach focused on the past, present and future of the mountain and its culture, is highly committed to gender perspective, with active presence in skilled commissions that investigate women involvement in Geosciences and participation in evaluation panels, with the final purpose to reach real gender equality in academia.

Identifying and tackling microaggressions within the Quaternary Sciences at levels implementable by individuals

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Microaggressions are seemingly insignificant words or actions that belittle, stigmatise or stereotype certain individuals, often without the person delivering the slight being aware or intending it to have a harmful impact. Microaggressions stem from (unconscious) bias or prejudice and reinforce feelings of exclusion and being an outsider. Individuals from under-represented groups in society are most likely to experience subtle, everyday microaggressions, bringing deleterious cumulative effects on well-being as well as participation and engagement in social and professional settings.

Discussions and proposals to increase diversity within the geosciences mostly consider systemic barriers within academic settings. Whilst these represent positive progress, the pervasiveness of microaggressions in the scientific community is rarely discussed. Virtually nothing is published publicly about identifying and tackling microaggressions within the Quaternary Science community.

This presentation therefore has two goals: (i) to formally and openly draw attention to microaggressions that are likely to be common in research environments, and indeed that someone may be experiencing right now in this conference centre; and (ii) propose some straightforward measures to address microaggressions and foster more positive, inclusive research cultures that are implementable at levels at which we as individual researchers have direct influence, such as within research groups or Society committees.

Drawing on collective insight and observations from initiatives the authors have implemented, participated in or commissioned reports into, we explore how to identify and tackle four forms of microaggression that may play out in the field, laboratory, classroom or at meetings: (i) mispronunciation of names; (ii) questioning one's heritage or ancestry; (iii) complimenting the sophistication of a researcher's scientific output or the eloquence of their spoken or written English and (iv) comments on visual appearance.

Democratizing palaeosciences for effective bidirectional communication

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Palaeosciences deals with disconnected past and it differs slightly from geoscience/Earth science as it is temporally in continuum with the past (Morthekai, 2019. Philosophies for the palaeosciences – a review. Proceedings of Indian National Science Academy 85 (1), 95 - 120). Although the 'present' is not the focus of palaeosciences, it is a methodologically required key to unlock the past. Considering the complexity in the palaeoscientific investigations, epistemological pluralistic approach is suggested where not only different disciplines come together but also people from various walks of life (with their own situated knowledge) should be involved in research activities in palaeosciences. It assumes implicitly that no lay persons, how marginalized they are, should be excluded. If excluded, the objectivity of the approach is skewed which lead both 1) to an incomplete knowledge of the present (loss for the palaeoscientists) and 2) to a degraded society in terms of scientific temper, and deprived of informed decision making on S & T projects (loss for the local civil society). This democratic participation of local civil society in palaeoscientific research activities is not only a good strategy to outreach (not only the majority ablests but all, possible) with an effective communication capacity but also society's valuable contribution back to palaeosciences.

Further, this type of democratic participatory nature of research activities has the potential to increase the adaptive capacity of the local civil society towards extreme climate events, because that is not only aware but also feel the responsibility to act towards mitigation and prevention.

Quaternary Quandaries: Transdisciplinary research and pedagogy in the India

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This paper seeks to discuss issues in the transdisciplinary and international nature of academic interactions in Quaternary palaeosciences with a specific focus on research within South Asia. We trace the evolution of interactions between Indian and foreign prehistorians and Quaternary scientists from the 19th c onwards, discussing the evolution of concepts and the impacts this had on the methodologies adopted to investigate the past. We also highlight issues related to the structure of research projects, sources of funding and resulting publications arising from such studies that have influenced perceptions of prehistory. We discuss the current state of research in prehistory and the impact of collaborative research on the same. We then move on to issues in pedagogy in the Indian context discussing the extent to which prehistory is incorporated into courses where other Quaternary palaeosciences are taught. We highlight the efforts of our Institute (Sharma Centre for Heritage Education, India), which has focused on holistic approaches towards understanding the past in the form of courses and workshops that stressed interdisciplinary participants and course structures. We conclude by discussing legal issues related to national and international collaboration within the country and issues therein, suggesting innovative ways in which these relationships may be fostered for the benefit of developing research and skills training within the nation. We conclude by discussing the need for the creative development of hybrid modes of pedagogy exploiting the vast potential for online modes of education, skills development and exchange of knowledge, thereby facilitating more comprehensive outreach and breaking barriers created by established hierarchies and funding.

Traces of Holocene extreme wave events in the Alykes coastal plain, Corfu Island

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Corfu Island is the northernmost of the Ionian Islands located in the eastern Mediterranean Sea. As a result of the collision of the African and the Eurasian plates, the island lies within an area of exceptional tectonic stress with all plate boundaries in its proximity. In the Adriatic Sea north of Corfu, the Adriatic microplate collides with the Eurasian plate, and to its south, in the Ionian Sea, the African oceanic plate is subducted beneath the Aegean microplate forming the Hellenic Arc. Earthquakes and co-seismic crustal movement which can cause extreme wave events have been recorded for the area. This paper presents geomorphological, sedimentary and microfaunal evidence of repeated tsunami landfalls in the Alykes coastal lagoon at the southwestern coast of Corfu Island. Using the radiocarbon dating approach, the beginning of the lagoon was dated back to at least the 6th millennium BC. Siltation of the lagoon was repeatedly interrupted by high-energy tsunami impacts. The most prominent tsunami traces were found for time immediately before 5.7 ka cal BC and the time between 5.2-5.0 ka cal BC. The ages of the tsunami events correspond well with local, regional, and supra-regional tsunami signatures found along the northwest and the west coasts of Greece. Subordinate traces for younger extreme wave events described by previous studies for the Gulf of Corfu were also detected in the Alykes palaeotsunami archive and seem to be partly related to co-seismic movements of the southern part of Corfu Island in the 4th century BC. The current study contributes to the understanding of the environmental effects of palaeotsunami impacts and underline a strongly non-uniform neotectonic behaviour of Corfu Island as a whole.

Poster - sessions 11, 14, 77, 120, 126, 164

SW Atlantic intermediate to deep water flow changes from MIS4 to Holocene: a sortable silt perspective

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Prof. Silvia Helena Mello e Sousa [1]***, Mr. Gilberto Dias*** [1]***, Prof. Rubens Cesar Lopes Figueira*** [1]

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Understanding the formation and circulation patterns of intermediate to deep water masses on different time scales is crucial for understanding the global thermohaline overturning circulation impacts on the Earth's climate. On the SW Atlantic continental margin, the northward flow of the Antarctic Intermediate Water (AAIW) and the Upper Circumpolar Deep Water (UCDW) is driven by the Intermediate Western Boundary Current (IWBC). In this study, we investigate intensity variations in the transport of AAIW and UCDW over the last c.a. 80,000 years, using the concept of sortable silt, a reliable proxy for current speed on the continental slope. We used grain-size data from three sedimentary records collected on the SW Atlantic slope, located at 840 mbsl (meters below sea level; modern AAIW and IWBC depth core), 1343 mbsl (current UCDW depth upper limit), and 1588 mbsl (modern UCDW depth core).

The results indicate that the average speed of the IWBC core (AAIW depth transport) is at least 15 $cm.s^{-1}$ faster than at the lower IWBC limit, where UCDW is transported. The minimum (15.5 $cm.s^{-1}$) and maximum (24.2 $cm.s^{-1}$) speed values obtained for the record under the IWBC modern core depth are compatible with those calculated for the current oceanographic setting. The results show abrupt changes in sortable silt (interpreted as changes in flow speed) in the transition between Marine Isotope Stage 4 (MIS4) and MIS3 and during MIS3, exclusively for the record retrieved at 840 mbsl. In addition, there is a clear coarsening of sortable silt from the Deglacial to the Holocene, indicating an intensification of the northward transport of the AAIW along the SW Atlantic margin. These results highlight a prevailing positive relationship between the northward carrier of the AAIW and the Atlantic Meridional Overturning Circulation over the last 80 kyr, with an antagonistic relationship at the beginning of MIS3 and over the Holocene.

For the cores located under the UCDW, the low average speed values (5.3 to 6.4 $cm.s^{-1}$) are compatible with the transition between the IWBC and the Deep Western Boundary Current (DWBC), which transports the North Atlantic Deep Water (NADW) towards the south.

The Holocene onset of the Plata Plume Water on the southeastern South American Shelf: a grain-size approach

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On the southeastern South American shelf, the discharge of the Río de la Plata, together with those from the Uruguayan and southern Brazilian lagoons, lead to the formation of a low-salinity water mass, the Plata Plume Water (PPW). This water mass presents a conspicuous seasonal regime, determined more by the intensity of the southerly winds than by the river discharge. In this sense, the knowledge of the plume´s variation is a valuable tool for recognizing the wind dynamics in the South Atlantic. This study aims to identify the input and variations of the PPW on the southeastern South American shelf by analyzing the grain-size end members.

We used two sediment cores collected on the southern Brazilian continental shelf in areas directly affected by the current flow of the Plata Plume Water (PPW). Both cores were radiocarbon-dated, and age-depth models were created for them. Grain-size analyses on decarbonated samples were made every 2 cm. From the grain size results, we performed grain-size end-member analyses.

The results allowed us to recognize a silty end-member, presenting a trend of increasing values towards the top of the cores. This silty fraction was interpreted as the distal, fine grain size fraction delivered from the Río de la Plata basin and associated with the sediments transported by the PPW. These sediments started to be deposited at ca. 8,000 cal BP when the Holocene sea level reached heights equivalent to the current times. The main change in sedimentation was observed at ca. 2,800 cal BP when the coastline position and the current oceanographic conditions were established in the southwestern South American region. Apart from the oceanographic control, we recognized the role played by the Holocene relative sea-level variations in the establishment and variations of the PPW. Our results agree with the conclusions raised by independent proxies in the same area.

Climatic temperature gradients during the Younger Dryas Stadial (GS-1) across the British Isles in chironomid-inferred temperature records

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The Younger Dryas stadial (GS-1; c. 12.8 to 11.7 kyrs ago), the last major abrupt cooling event in the North Atlantic region at the end of the last glaciation, provides an excellent opportunity to investigate the timing and nature of climatic changes. Knowledge of spatial variations in temperature in response to abrupt climatic transitions is essential to understand potential future climatic change. Numerous studies, with varying degrees of chronological control and sampling resolution, have described two or more phases during the Younger Dryas from records around the North Atlantic region based on reconstructions of sea surface temperatures, hydrological change, and windiness. It is critical that the climatic structure of the LLS/YD is better understood as numerous forcing mechanisms and processes have been proposed to explain the multiple phases observed. These include changes in AMOC strength, sea-ice extent, polar jet stream location and Westerly strength.

Relatively little attention has been given to temperature variations expressed in chironomid-inferred temperature (CI-T) records during the Younger Dryas, yet they can provide high-resolution (decadal-scale) mean July air temperature estimates. In this study, chironomid analysis was applied at a high temporal resolution to a number of lake sequences from spatially diverse locations across the British Isles, including Old Buckenham Mere in the southeast of Britain, Llangorse in south Wales and Crudale Meadow in the Orkney Isles. The new C-IT records are combined with previous studies to generates a palaeoclimatic database. These records lie on W-E and N-S transects across the British Isles allowing the spatial variability of the structure and magnitude of temperature change to be explored. All three of the new sites display a three-phase structure. Old Buckenham Mere displays this most clearly with an initial cool period (c. 11 °C) from 12.7-12.5 kyrs ago, warmer temperatures (c. 13 °C) then occurred between 12.7-12.4 kyrs ago, followed by a return to cold (c. 10 °C) and gradually warm into the Holocene. Our new records suggest that there is greater variation in temperature change during the LLS than previously observed.

Changes in the global ocean during the last deglaciation from a model-data perspective

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The early last deglacion (~19-15 ky BP) was a period of rapid climate change. It is characterized by the onset of atmospheric CO2 raise and land ice reduction that eventually lead to the Holocene climate state. The ocean processes involved in deglacial climate change are still under debate, with freshwater fluxes in different basins, changes in winds, ocean circulation, and biogeochemistry, as possible drivers of carbon transfer from the deep ocean to the atmosphere. Carbon isotopes in benthic foraminifera samples from sediment cores show variations during the early last deglaciation, that act as tracers of changes in deep water mass structure, ventilation, and export production. Here we compare the global deglacial benthic foraminifera δ13C database from the Ocean Circulation and Carbon Cycling (OC3) project with different transient global, isotope enabled, ocean model simulations. The goal is to constrain the different ocean changes that can explain variations in δ13C during the early last deglacation. This is the first time that a global synthesis of benthic foraminifera δ13C is compared one-to-one with modeled δ13C from transient simulations, with both spatial and time dimensions taken into account in a four-dimensional analysis.

Chironomid-based reconstruction of Holocene July temperatures: new training set from Eastern Europe and its application

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The life cycle of non-biting midges from the family Chironomidae (order Diptera) depends on the ecological conditions of the water body, where larvae live (trophic state, oxygenation level, etc.) along with climatic factors, mainly average July temperature. Therefore, sub-fossil Chironomidae remains deposited in lakes and bogs provide a record of the past terrestrial and aquatic environment and could quantitatively reconstruct the environmental conditions.

Collecting modern analogs training sets and producing transfer functions based on them is the primary approach in paleo-Chironomidae research. I have created new Baltic States training set which covers understudied territories of Estonia, Latvia, and Lithuania. July average temperature range Baltic States transect is 1,5 ^{o}C. New data was merged the already published Finnish training set. Furthermore, some published sites from Poland were added to the Finno-Baltic training set. The final Finno-Baltic-Polish dataset contains 121 sites and has a temperature gradient from 11,0 ^{o}C up to 19,0 ^{o}C.

Based on the Finno-Baltic-Polish training set developed a new inference model using weighted averaging-partial least squares (WA-PLS) regression outperformed with maximum likelihood regression. The normalized root mean squared error (RMSEP) of the training set performance is 0,43 ^{o}C, the maximum bias is 0,35 ^{o}C, and R2 is 0,94. The Finno-Baltic-Polish inference model was applied on several lake long cores from Baltic States (300-13500 years BP) and resulted in the July air temperature reconstruction with an average error of 0,82 ^{o}C. Thus, the new Finno-Baltic-Polish training set provides the best modern analogs of Chironomidae communities to perform paleo-temperature modelling in the Baltic States region.

Clipperton coral d13C variability and its relationship to the rate of anthropogenic CO2 uptake

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Since the 1850s, human activities have released a large quantity of CO_2 into the atmosphere. Anthropogenic CO_2 is depleted in ^{13}C leading to a continuous decrease in atmospheric $d^{13}C$ as the atmospheric CO_2 concentration continues to increase. The ocean is one of the main global sinks of anthropogenic CO_2 emissions which contribute greatly to reduce the effect of the global climate warming. However, the flux of CO_2 between the atmosphere and the ocean is not spatially homogeneous, especially in the tropics, where a mosaic of CO_2 sinks and sources is observed. The effectiveness of these zones also varies over time mainly at the decadal timescale. A better understanding of the variability of this CO_2 pump over the last centuries would improve predictions of the future evolution of these areas according to the different scenarios proposed by the IPCC.
Variations in the surface Dissolved Inorganic Carbon $d^{13}C$ ($d^{13}C$-DIC) make it possible to estimate the oceanic uptake of atmospheric CO_2. Nevertheless, there is only a limited amount of instrumental data of $d^{13}C$ -DIC, covering short time periods that cannot resolve its variations at decadal timescales. It is therefore necessary to find a marker of the variability of $d^{13}C$ -DIC that allows us to reconstruct the variability of the oceanic absorption rate over the last centuries in key areas of the tropical band.
This study that builds up on previous work will present Clipperton atoll coral $d^{13}C$ data as a proxy of $d^{13}C$-DIC variability over the last centuries. These geochemical data coupled with a modelling approach will give insight into the temporal variability of the rate of oceanic absorption of the anthropogenic CO_2 signal in the South East Pacific area.

crestr: An R package to perform probabilistic climate reconstructions from palaeoecological dataset

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Quantitative climate reconstructions are fundamental to scaling past environmental changes. In particular, the proliferation of pollen-based reconstructions during the past decades has been instrumental in improving our understanding of past climate dynamics across various spatial and temporal scales. However, this knowledge has been mainly concentrated in North America and parts of Eurasia, and very few quantifications exist in the tropics. This global data imbalance is partly due to the sparser network of supporting pollen records in these regions and, in equal proportions, to the limitations of the most commonly used reconstruction techniques (e.g. the analogue technique or WA-PLS) in dealing with the specificities of tropical vegetation. To address this problem and produce the much-needed climate quantification from tropical regions, we propose using the probabilistic method CREST (Climate REconstruction SofTware) that uses probability density functions ('pdfs') fitted on modern occurrence plant data to reconstruct environmental parameters. CREST, which has been successfully employed in the Africa and South America, offers many advantages over the classical approaches, including 1) a higher flexibility of application, 2) a better capacity to estimate uncertainties, and thanks to the recent developments of a dedicated R package crestr that includes a global calibration dataset, 3) CREST is applicable in every environment where plants currently grow. Considering these advantages, the large-scale application of CREST to quantitatively reconstruct important climate parameters from the existing tropical fossil pollen records should 1) help better integrate and interpret regional proxy compilations, 2) shed light on the spatiotemporal climate variability of tropical regions, and 3) determine the main modes of tropical climate variability. With this contribution, we will showcase the use of the crestr package with a novel temperature reconstruction derived from the 270,000-year-long, high-resolution pollen record from Laguna Fùquene in Colombia, and discuss how this type of analysis could be generalised to determine spatial patterns of climate change from multi-record reconstructions

Variations in the strength of the Atlantic Meridional Overturning Circulation during the Holocene

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Based on the geochemistry of foraminifera shells, the past strength of the Atlantic Meridional Overturning Circulation (AMOC) can be indirectly reconstructed by sea surface temperature, sea surface salinity, and CO_2 trapped by deep-water formations. While the AMOC plays a key role in climate variability, precise variations of the AMOC strengths and climate-related responses are still equivocal. The Holocene is an ideal period to further develop our knowledge of the natural climatic and oceanic variability from well-preserved microfossils. The aim of this study is to reconstruct the AMOC in a deep-water formation area (e.g., surface and bottom water) to obtain high-resolution strength variations. To investigate these variations, we used benthic and planktic foraminifera assemblages and geochemistry. Our study focuses on Core U1314, located in the Iceland basin (56° 21.8' N, 27°53.3' W), which is one of three deep-water formation areas in the North Atlantic. The core has been divided into 3 cm sections, 5 cm apart, to obtain a final resolution of 300 years. Preliminary results reveal four dominant species (from the most abundant to the lowest): Globigerina bulloides, *Neogloboquadrina incompta*, *Neogloboquadrina pachyderma (s*) and *Globigerina quinqueloba*. The early Holocene shows a warming trend with an increase of *G. bulloides* (40% to 63%). Additionally, there is a decreasing trend in *N. incompta* (from 40% to 28%). Although the late Holocene is still dominated by G. bulloides (ranging from 37% to 54%), a brief dominance of *N. incompta* (49%) appears at 4.000 years B.P., which indicates a freshening at this time. Additional trace element analyses (Mg/Ca) and stable isotope analyses ($\delta^{18}O$ and $\delta^{13}C$) will be conducted on benthic (*Hoeglundina elegans*) and planktonic (*G. bulloides* and *N. incompta*) foraminifera to reconstruct paleotemperature of bottom water and sea surface. The expected results will provide 1) a high-resolution dataset of bottom and sea surface temperatures; 2) an overview of the AMOC millennial cycle; and 3) a better understanding of the feedback mechanisms that influence the AMOC in the Holocene and their impact on the global climate. Therefore, the reconstruction of the AMOC strength variations can provide insight into future global warming.

Using lakes as isotopic precipitation gauges to constrain inflow seasonality and evaporative enrichment

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Lake-water-derived proxies have the potential to store information about both large-scale circulation changes and catchment-integrated processes. Lacustrine carbonates, cellulose, and aquatic organisms incorporating the stable isotopic composition of lake water hydrogen (d2H) and oxygen (d18O) can indirectly archive the isotopic composition of precipitation in the geological past. However, despite similar precipitation input, the lake water isotope values may vary greatly within a region due to variable influence of inflow (precipitation) seasonality and evaporative enrichment. Moreover, the relative sensitivity of each lake to these controls may vary through time. One way to quantify spatial and temporal variation in lake water isotopic composition is modern lake water monitoring. Furthermore, studying present-day conditions allows us to directly link isotopic changes to observations of atmospheric circulation change. From 2018 to 2022, we have measured the stable water isotopic composition of 135 lakes in northern Norway, Finland, and Sweden through a sampling campaign in the first week of July each year. The sample collection is focused along a coastal-to-inland transect, extending from the Norwegian Sea in northwest to Bothnian Bay in southeast. We find that the lakes display variable sensitivity to changes in inflow isotopic composition and to evaporative enrichment, and that these controls vary in both time and space. The water isotopic composition of coastal lakes is mostly sensitive to distillation during moisture transport, whereas the isotopic composition of inland lakes also reflects evaporation. To estimate the inflow isotopic composition of evapo-concentrated lakes (d2HI), we used a Bayesian method. For instance, more depleted d2HI in 2020 than in 2019 indicated more 2H-depleted and/or more winter precipitation inflow to the lakes in 2020, explained by extremely positive Arctic Oscillation (AO+) conditions. We find evidence that lake water isotopic variability in this region reflects a combination of seasonal precipitation changes associated with atmospheric circulation changes, and catchment-integrated evaporation. Careful consideration of the variable sensitivity to these processes is essential when inferring past climate from lake water isotope proxies.

Oceanographic variability by SE Greenland over the past 2000 years

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The interdisciplinary GreenPlanning project addresses an important question in climate science: *Does Greenland ice sheet melt affect weather fluctuations in Europe*? Model studies suggest that certain climatic modes with blocking of high pressure systems can hinder warm moist air from reaching Northwest Europe, and that these conditions are instigated by changes to sea surface conditions near Greenland. To test this hypothesis, the GreenPlanning project will establish a 2000 year long record of changes to the modes of climate variability in the North Atlantic and a record of Greenland Ice Sheet melt water fluxes.

An important brick to this puzzle is the ocean variability near Greenland over the past 2000 years. The Atlantic waters may modulate the amount of ice sheet melt and in return have their temperature and salinity modulated by melt water from the ice sheet. Paleoceanographic data from the SE and W Greenland shelf region document that temporal changes to the sea surface temperature and flow of Irminger Current is transmitted to Greenland's shelf and can be reconstructed from shelf sediment cores. Thus, potentially providing additional insight into the Irminger Ocean sea surface temperature changes. Here we present an overview of the past 2000 years of variability in Atlantic waters on the SE Greenland shelf based on foraminifera assemblage analysis and alkenone paleothermometry.

Variations of bottom current activity in the Korea Gap, East Sea (Japan Sea) since 35 ka

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This study reconstructed variations of bottom current activity based on the changes in sedimentary facies and detrital grain-size distributions of the levee deposits at the bottom-current channel in the Korea Gap. Since the Korea Gap serves as a conduit of deep-water circulation between Japan and Ulleung basins of the East Sea (Japan Sea), it is suggested that bottom current activity in the Korea Gap have been regulated by the deep-water circulation changes. Based on sedimentary facies analyses, intermittent turbidite beds deposited by the turbidity currents from the surrounding slopes were discriminated from the normal background deposits by hemipelagic settling and bottom-current reworking. The age-model for the normal background sedimentation since 35 ka shows an extremely high sedimentation rate up to 46 cm/kyr during about 17 to 11 ka, which is ca. eightfold higher than that of the last glacial period (5.5 cm/kyr) and ca. fourfold higher than that of the Holocene (12 cm/kyr). Such abrupt increase in sedimentation rate suggests a vigorous bottom-current activity which might have facilitated erosion in the bottom current channel axis and rapid deposition of the reworked sediment in the channel levee during the late-glacial period. The mean size of "sortable silt" from the bottom-current deposits, representing the bottom current velocity, fluctuated significantly with *ca.* 0.34-0.70 kyr periodicity. Hence, deep-water circulation in the East Sea was very unstable during the late glacial period, varying with centennial periodicity

Luminescence chronology of point bars and their utilisation in Past discharge estimation in the Southern West Bengal.

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Point bars are sinuous accretionary wedges of sand and finer sediments deposited by laterally migrating meandering rivers. They provide an excellent means to study past environments due to their ability to preserve the sedimentary structures corresponding to alteration in energy conditions. At the same, the dimension of the meander loops is directly proportional to the discharge of the river and the type of sediment load. The present work aims to study the point bars in Southern West Bengal to calculate the past river discharge and thus reconstruct the past climate. Luminescence dating is applied on the point bars to build the chronology. Field investigations and grain size analysis of point bar sediments supported by luminescence ages have shown point bars as a potential proxy for paleoflood and paleodischarge estimation. The study reveals that the region received good rainfall during reported periods of intense monsoon (Medieval Warm Period, Sub Altantic Period, Sub Boreal Period) and remained devoid of discharge during cold or dry events. (Little Ice Age) and 4.2 ka dry event (Meghalayan aridification).

Reconstructing tropical South Pacific hydroclimate during the late Holocene using proxies and models

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Hydroclimate in the tropical South Pacific is dominated by the South Pacific Convergence Zone (SPCZ), a region of low-level convergence responsible for providing fresh water to 11 million people. The SPCZ is known to change in orientation and intensity in response to interannual climate phenomena (e.g., ENSO), although the impact of decadal and centennial scale climate cycles on the SPCZ is unclear. As such, our ability to predict long-term changes in South Pacific rainfall is low, which is likely to hamper societal responses to future climate change. To increase our understanding of the mechanisms driving SPCZ variability, we have reconstructed changes in precipitation across the tropical South Pacific over the past 3.5 ka. We have used a combination of organic and inorganic geochemical proxies to generate decadal-scale precipitation records from 3 islands across French Polynesia to constrain changes in the eastern side of the SPCZ. Additionally, using previous proxy reconstructions and climate model simulations, we have performed a data model assimilation to evaluate how the SPCZ has changed in intensity and orientation over the late Holocene, allowing us to evaluate the relationship between decadal-scale global climate periodicities and tropical South Pacific precipitation.

Implementation of the Neodymium oceanic cycle in the iLOVECLIM model (EMIC)

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An improved understanding of the mechanisms involved in the Neodymium (Nd) oceanic cycle is needed to better interpret past archives. Recently, climate and ocean models (e.g. FAMOUS-MOSES1, Bern3D, CESM1.3, COCO, OCIM-GNOM and NEMO-PISCES) incorporated the neodymium isotopic composition of seawater to have a broader view of these mechanisms, but also to simulate and understand neodymium isotopic composition as a tracer of the modern and past oceanic circulation .

Here, we aim to implement the Nd oceanic cycle in the Earth System Model of Intermediate Complexity (EMIC) *i*LOVECLIM. The Nd implementation in *i*lOVECLIM is following the state-of-the-art Nd scheme as implemented in previous studies, with the incorporation of the atmospheric dust source, the river source, the boundary exchange as well as the recently highlighted bottom sediment flux. We will also include the reversible scavenging for the sink term. Due to this computational efficiency of the *i*LOVECLIM model, numerous simulations will be carried out for a fine tuning of the key parameters, such as the scavenging efficiency and the bottom sediment flux.

Moreover, we aim to provide an improved framework on the interplay between Arctic Ocean, carbon cycle and the Atlantic Meridional Oceanic Circulation (AMOC) via an extensive data-model comparison, including new simulation and Nd isotope records for the Last Interglacial period and the Last two deglaciation.

Humid phases in western Europe since 5 ka and their synchronicity with Northern hemisphere climate changes, insight from neritic and coastal deposits

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The detection and understanding of natural climatic modes appear to be critical for improving the predictive capacities of climate variations since the Anthropocene onset. This has recently led to major compilation and inter-comparison works on past climate series targeting the Holocene in particular. A key objective of paleoclimatology is indeed to supplement the short temporal extension of the instrumental data, in order to draw up an inventory of past climatic situations, analogous or contrasting with the current period, able to provide us with a better knowledge of the natural sensitivity of the climate (threshold periods, extremes, etc.).

The present work focuses on coastal and neritic archives from the inner margin of the Bay of Biscay off Aquitania and on the humidity signals that have been trapped within those sediment series along the five last millennia. Paleosoils especially, developed in the shore dune systems of the Bay of Biscay sand beaches, are since long attributed to the persistence of centennial humid climatic phases affecting western Europe border during the Holocene. Several attempts have been done to correlate the regional occurrence of those paleosoils to global climatic conditions, with sometimes an inverse approach targeting the datings of sand dunes and of their mobility episodes rather than the rich paleosoil records themselves. Here we revise the chronology of those deposits *a priori* related to wet climatic conditions and question their interpretation in terms of oceanic and atmospheric forcings. The coherence of the main humid events detected in this context will be tested at regional scales and their phasing with climatic oscillations detected at the boreal Atlantic scale will also be questioned.

Coccolith vital effects for the development of climate proxies

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To understand how coccolithophore calcification rates evolved, it is critical to disentangle which environmental parameters are responsible to modulate the flow of energy and resources from photosynthesis to calcification. The values of coccolith vital effects, the offset of the isotopic composition of coccoliths from abiogenic calcite equilibrium, are not yet unilaterally understood.

To explore the suitability of coccolith isotopic values to produce consistent estimations of calcification intensity under contrasted boundary conditions, we analyze the $\delta^{13}C$ values and coccolith vital effects recorded in size-separated coccolith fractions in the modern ocean across key environmental gradients, from core top sediments. Size separations are based in the application of the method by Minoletti et al. (2009) and serve to produce nearly monospecific isolated coccolith fractions.

We will investigate the variance of size-separated coccolith vital effects and PIC/POC (Particulate Inorganic Carbon/Particulate Organic Carbon) estimations with environmental change and independent indicators of coccolith calcification, obtained from the application of detailed coccolith morphometrical analysis with the use of different techniques of microscopy and image analysis.

Weaker North Atlantic surface circulation during Common Era centennial-scale cold anomalies associated with Caribbean salinification

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Paleoceanographic reconstructions show pronounced centennial variability in sea surface temperature and salinity (SST, SSS), and circulation in the subpolar North Atlantic during the Common Era (CE). In particular, weakening of the surface circulation in the high latitudes associated with advection of Arctic sea ice into the Labrador Sea has been invoked to explain cold climate in Europe during the Little Ice Age. In contrast, upstream changes in the tropical Atlantic remain underrepresented due to the paucity of records covering the CE, rendering our understanding of interactions between these oceanic sub-basins incomplete. Here, we reconstructed centennial SST and SSS variability in the Caribbean Basin over the last two millennia using Mg/Ca and $\delta^{18}O$ in mixed-layer dwelling planktic foraminifera. The SST/SSS changes occur contemporaneously with (hydro)climate anomalies in the North Atlantic and Americas, suggesting a common forcing mechanism resembling the modern Atlantic Multidecadal Oscillation. Cold phases around 500-650, 750-900 and 1400-1600 CE were associated with Caribbean salinification and Gulf of Mexico freshening, implying that weaker North Atlantic surface circulation during these periods was associated with reduced northward transport of tropical salt. Our data suggest that changes in tropical ocean salinity played an important role in shaping subpolar and global-scale climate variability during the CE.

Reconciling the Antarctic temperature – δ18O relationship on different time- and spatial scales

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Water stable isotope ratios ($\delta^{18}O$, $\delta^{2}H$) in polar ice cores are a widely-used proxy for site temperature, yet their calibration has remained challenging. The temperature-$\delta^{18}O$ relationship is strongly dependent on the spatial or temporal scale under consideration. In Antarctica, spatial regression of $\delta^{18}O$ and surface temperature (T_S) yields a slope of ~0.8 ‰ K^{-1}; temporal regression using the seasonal cycle yields 0.21 to 0.57 ‰ K^{-1}; and the (site-dependent) glacial-interglacial temporal regression slope ranges from 0.8 to 1.45 ‰ K^{-1} in recent estimates. Precipitation isotopes are controlled by the condensation temperature (T_C) that is warmer than T_S owing to the strong near-surface inversion. The T_S - T_C relationship differs on spatial, seasonal, and glacial-interglacial scales, further complicating climatic interpretation of $\delta^{18}O$. A comprehensive description of Antarctic isotopes thus requires a description of the relationship between six different isotopic slopes ($\delta^{18}O$ variations on 3 spatial/temporal scales, each regressed onto T_S and T_C).
First, we will give a short overview of recent estimates of the glacial-interglacial $d^{18}O$-T_S regression slope based on borehole thermometry and empirical estimates of the gas age-ice age difference (Δage). Next, we combine isotope-enabled simulations using CESM (Community Earth System Model) with an analytical approach called *Unified Slope Equations* to provide a description of the relationship between the six aforementioned isotopic slopes. Surprisingly, our analysis suggests that the seasonal $\delta^{18}O$-T_C regression slope is a good estimate of the glacial-interglacial $\delta^{18}O$-T_S regression slope: indeed, at Dome C the former is 1.16 ‰ K^{-1} in observations (monthly averages, r = 0.9) while the latter is 1.14 ‰ K^{-1} borehole-based reconstructions. Our framework can reconcile the initially contradictory and disparate isotopic slope estimates found in the literature, and suggests a new observational way to calibrate the ice core isotope paleothermometer.

2000-year variability of the North Atlantic Current: Insights into AMOC dynamics?

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Over the last 2000 years, the climate of the North Atlantic region was punctuated by centennial oscillations, which despite their small magnitude had important societal impacts, particularly in NW Europe. The most favoured explanations for this climate variability invoke changes in external forcings which were likely amplified by ocean-ice-atmosphere feedbacks. Traditionally, ocean changes, specifically the strength of the Atlantic Meridional Overturning Circulation (AMOC) have been invoked to explain some of this centennial climate variability. However, new research suggests that the strength of the subpolar gyre and its northward heat transport by the North Atlantic Current likely contributed to the climate variability recorded in Europe. In this study, we explore the hydrographic variability of the North Atlantic Current using four subdecadally to decadally resolved sediment cores that lie within the pathway of this watermass. New and published foraminiferal-based temperature and salinity reconstructions from these four locations are combined to study their common variability and obtain a robust reconstruction of the North Atlantic Current across the last two millennia.

Plant macrofossil-based Lateglacial temperature seasonality reconstructions for the Baltic States region – a methodological comparison

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The Younger Dryas (YD; ca. 12.8–11.7 ka BP) represents an abrupt climate shift and is traditionally referred as a generally cold period in Europe. More recent studies have proposed that YD is rather linked to a distinct rise in temperature seasonality in Northern Europe due to an abrupt winter cooling and only modest cooling or even a slight warming in summer. However, a robust test of this hypothesis remains elusive, partly due to paucity of proxy data reliably recording winter temperature conditions in higher northern latitudes.

In this study we reconstruct temperature seasonality patterns of YD using plant macrofossil datasets from 13 sites of the Baltic States and surrounding region. Plant macrofossils, while representing local environment, typically face a high risk of incomplete data through false absences caused by low dispersal ranges and relatively high decomposition rates. This shortcoming is balanced by strengths including better taxonomic resolution and less noise from long-distance transport compared to commonly used pollen data. This has led to an increased interest in plant macrofossils as a climate proxy in the recent years. Consequently, a range of new species-based climate reconstruction approaches compatible with plant macrofossil data have been introduced. Here we compare multiple classical and novel climate reconstruction approaches to reconstruct January and July mean air temperatures using plant macrofossil assemblages. Methods tested here include the traditional Mutual Climate Range and recently developed CRACLE, CREST and Minimum Temperature Limit approaches. Additionally, we test the influence of different modern climate datasets and geographic calibration areas on the temperature reconstructions.

In the aggregate, the results of each method, when using the same calibration region, are similar to one another in relative temperature trends throughout the reconstructed time period, while their absolute values can vary by several degrees. Both summer and winter YD temperature trends are highly dependent on site data quality (species assemblages and sample resolution) and differ between calibration regions used. Nevertheless, our ensemble reconstructions from combined data of 13 sites indicate a strong tendency for increased YD seasonality with strong winter cooling and moderate to no summer cooling, when a global calibration is used.

Preliminary proxy data from a Pleistocene deep lake sediment core from eastern Romania

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We present here the environmental context and preliminary results from the analysis of a recently retrieved 60 m long core from the Obanul Mare paleolake (Mangalia, Romania). The 300 m wide, fully closed Obanul Mare doline is part of a group of dolines that formed through the opening of underground voids. These dolines were subsequently flooded by groundwater and some of them still function as active lakes, the largest of them being Mangalia Swamp with a diameter of ~1 km.

Our aim is to extract multi-proxy information from these sediments and gain insights into the environmental conditions that prevailed during the sedimentation history of Obanul Mare. The most important aquifer feeding these type of lakes is mesothermal and sulphidic and its level is controlled by that of the nearby Black Sea. By identifying periods with sulphidic, meteoric or even sea water recharge, we would also be able to constrain periods of Black Sea level fluctuations.

Magnetic susceptibility and loss on ignition data indicate that deposition took place across several glacial-interglacial cycles of, probably, Pleistocene age. The sediment column comprises five main lithological units in which the fine fraction is dominated by the presence of silts (50%), while clays are the secondary component. These lithological units are: recent soil and brown clays from surface to 10 m, yellowish deposits (that could be interpreted as wind-blown material that deposited as loess in the surrounding region) from 10 to 15 m, a yellowish-reddish unit between 15 to 25 m, a dark grey unit until 42 m, and a light grey unit rich in gravels and limestone blocks between 42 and 60 m.

From the entire core length we analyzed a wide range of proxies, including polyaromatic hydrocarbons and microcharcoal, $\delta^{18}O$ and $\delta^{13}C$ from freshwater shell fragments, $\delta^{13}C$ and $\delta^{15}N$ in organic matter, as well as the chemical composition of these sediments.

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Palaeoenvironmental evolution of coastal ecosystems: La Janda (SW Iberia)

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Coastal ecosystems are shaped by the interplay of different factors, such as climate, tectonics, sea-level changes, human activities, etc., which make them highly dynamic areas that have undergone significant changes over time. Considering the sensitivity of the vegetation to these factors, its study from a long-term perspective may provide insights into the environmental evolution and serve as past analogues to understand the impact of natural and anthropogenic changes.

The study of several sedimentological cores drilled in La Janda (SW Iberia) allowed identifying a succession of different phases and environments during the Holocene in this region. The fluvial system existing during the Early Holocene was progressively transformed by the marine transgression and, after a period of transition, resulted in the development of a restricted bay. The reverse process occurred during the Late Holocene with a gradual silting up of the restricted bay until anthropogenic facies were recorded in the upper part.

Here we present the multiproxy research that was carried out in one of the cores, the S3, combining palynological, sedimentological, and geochemical analyses.

Quantitative reconstruction of Holocene vegetation and seasonal temperature change in Northeast China

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The Holocene temperature conundrum has been the subject of intense debate in the studies of Holocene climate changes. Pollen-based quantitative reconstructions of seasonal temperature change in different regions provide an important approach to study this conundrum. Northeast China is located on the northern margin of the East Asian monsoon region yet has obvious gaps and deficiencies for quantitative reconstruction. Although studies of different archives in this region were conducted, the Holocene climatic history and mechanism remain debatable. Moreover, the high-resolution record that can reflect the decadal to centennial variability is rare. Here we reconstruct vegetation and climate changes during the last ~ 10000 years BP based on a high-resolution pollen record from Gushantun peatland, Changbai Mountains. Multiple quantitative reconstruction approaches were used and weighted averaging partial least squares regression (WA-PLS) was chosen as the most appropriate method to reconstruct Holocene temperature and precipitation time series and the history of seasonal temperature change was revealed. The reconstruction result shows that the Holocene Climate Optimum was in early to mid Holocene with ~2°C warmer than modern temperature in the coldest month and it gradually cooled during late Holocene with minimum -19.6°C. Cold events occurred around 9.2 ka BP, 7.8 ka BP, 5.8 ka BP and 2.3 ka BP with variation amplitudes from 1.5 to 3°C. The synthesized seasonal temperature time series and the comparison with other proxies show that the decreasing trend of mean annual temperature is not a seasonal bias caused by summer temperature change. This study provides evidence for seasonal temperature change on regional scale during the Holocene, reference for further understanding of the Holocene temperature conundrum and data support for the investigation of vegetation feedback and projection models of future climate change.

Temperature changes in southern France (Canroute, Massif Central) over the last 14,000 years: a quantitative reconstruction based on pollen and lipid tetraethers (brGDGT)

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The climate of the southern Europe/Mediterranean area is characterized, during the Holocene, by a strong spatial and temporal heterogeneity whose patterns and mechanisms are still poorly understood. The proxies used to reconstruct quantitatively past climate changes are based most of the time on pollen, as well as a few speleothems and chironomids for terrestrial temperatures and alkenones for SSTs (Sea Surface Temperatures). Studies based on molecular biomarker data in the continental area are rare. Studies based on coupled pollen/molecular biomarker approaches are even more scarce, despite the interest in such multi-proxy studies. Here we propose an approach combining pollen and brGDGTs (branched Glycerol Dialkyl Glyceryl Tetraethers) applied to the Canroute well-dated peat sequence to document the climatic changes of the last 15,000 years in the south of Massif Central (France). We also compare the climate pattern inferred at Canroute from both proxies to the more regionally known climate pattern from surrounding climate archives. To achieve this, a pollen-based transfer functions approach is tested, combining three modern pollen dataset calibrations to four different models (MAT, WAPLS, RF and BRT). For molecular biomarkers, nine calibrations based on soil and peat calibrations are tested, and the more reliable is selected depending on the accuracy of the temperature quantified for surface samples.

The confrontation of the Canroute signal with those of various sites located in southern Europe shows a coherent climatic signal with a global warming trend during the Tardiglacial. The Holocene shows more contrasted trends between sites and proxies, but overall, the Canroute signal appears coherent with most of the regional signal. The presence or absence of a Holocene Thermal Optimum still cannot be confirmed although the Canroute signal seems to point to its presence for the south of the Massif Central. Results highlight the importance of considering environmental and ecological constraints to better understand pollen data and brGDGTs-inferred temperature reconstructions. Moreover, the multi-proxy approach points out the importance of investigating the evolution of the local environmental context for a better understanding of the reconstructed climate parameters, as local changes in environmental conditions could impact pollen records and the brGDGTs-producing bacterial community.

Tracking shifts in the westerlies at Baboon Lakes, central Sierra Nevada, California over the last 12,000 years

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Extreme drought has led to critical water shortages with increased fire activity in the American West and a need for more accurate climate predictions. The past hydrology of this sensitive region could afford unique insight into potential patterns and mechanisms of future water availability. Latitudinal migration of the westerly winds and associated storm tracks may play a primary role in controlling precipitation patterns over much of this region. However, few records have documented past shifts in wind patterns independently from precipitation variations. The Sierra Nevada are key for studying this problem as the mountains steer incoming storms either north or south of the range, depending on location of the westerlies. Thus, this region is not only a potential contributing factor to the spatial pattern of droughts, but also is ideal for isotopic tracking of the westerlies, because the isotopic difference in storm tracks between north and south-shifted positions is large.

Here, we use plant wax isotopes preserved in lake sediment cores from the high-elevation Baboon Lakes of the Sierra Nevada, California to reconstruct the relative position of the westerlies and hydrologic changes over the last 12,000 years. We pair these analyses with pollen and charcoal data to assess coeval variations in plant communities and fire history. An understanding of the westerlies' influence on regional precipitation patterns and the mechanisms behind shifts will inform models used to predict precipitation patterns and the snowpack levels of the Sierra Nevada more accurately.

The Baboon Lakes sediment record covers the last 12,000 years and documents fluctuations between low organic content clays and more organic-rich sediment. Sediments have high concentrations of plant-derived *n*-alkanes with chain lengths ranging from C21-C33 and terpenoids specific to conifers and angiosperms. The long-chain *n*-alkane $\delta^{13}C$ values are consistent with mixing of plant waxes derived from both conifers and angiosperms. Select *n*-alkane $\delta^{13}C$ values are high, suggesting the conifers grew under high water stress conditions. The $\delta^{2}H$ of these alkanes is underway to be used as a SHW position proxy. This will be tested with a pollen assemblage and compared to a charcoal record.

Bulk organic matter δ13C and δ15N data of a sediment core from Obanul Mare paleolake, SE Romania

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We present here preliminary $\delta^{13}C$ and $\delta^{15}N$ measurements of bulk organic matter from a 60 m deep paleolake core. The sedimentary sequence was deposited over several glacial/interglacial cycles and consists of five clay and silt main units.
Bulk sediment samples from different depths were taken for isotopic analysis and were prepared following three different protocols. All the methods considered were based on the usage of aqueous-acid treatment and adapted to ensure complete removal of inorganic carbon and the prevention of organic carbon loss, especially for samples with low content of organic matter.
The samples were measured on a Nu Instruments Horizon 2 IRMS coupled to a EuroVector 3024 elemental analyzer. After acid treatment, an amount of ~20 mg was analyzed and we determined that the organic C content varies between 0.9% and 0.2%, while the N content varies between 0.09% and 0.02%, resulting in C/N ratios of 7 to 11.
Neighboring extant lakes, similar to Obanul Mare, are fed by underground mesothermal water rich in H_2S and CH_4 (methanotrophs form the basis of methane-driven food chain), sustaining chemoautotrophic ecosystems. By analyzing stable C and N isotope values we can constrain periods when the lake was fed by sulphidic water, whose level is controlled by the level of the nearby Black Sea.
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Anthropogenic pollution impact and recovery of a Swiss run-of-the-river reservoir based on paleolimnological water quality indicators (diatoms, chironomids)

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Wohlensee is a run-of-the-river reservoir created in 1920 by the construction of the Mühlberg hydroelectric power station and the damming of the Aare river, a mid-sized river originating in the Swiss Alps, downstream of the city of Bern (Switzerland). Wohlensee has been significantly affected by increasing anthropogenic and industrial pressures in the mid-20th century (population growth, agricultural and industrial development). Our aim was to investigate how and to what extent the diatom and chironomid communities, generally considered to be excellent indicators of water quality, have changed in the lake since the dam on river was built, and to what extent the discharge of untreated industrial and municipal wastewater into the Aare had an impact on species diversity within these indicator groups. Sediments were collected with a Piston-type corer in 2014 and dating of the sediments was based on ^{210}Pb and ^{137}Cs analyses.

The results of the analysis of chironomid larval head capsules indicate a very high level of organic pollution from ca 1940 to 1950, when the chironomid species composition changed completely. These changes suggest a high load of nutrients and organically degradable substances in Wohlensee. From about 1965, the chironomid larval community slowly recovered. A similar trend was observed in the diatom analyses. The proportion of planktonic diatoms increased significantly in the middle of the 20th century. This indicates an increase in the nutrient load in the water body, in which planktonic diatoms can only thrive under high growth rates and high nutrient availability due the low water retention time in this river-fed reservoir. The first signs of ecosystem recovery appear in the 1960s, but it was not until the very end of the 1980s that significant changes in the species composition of diatoms were observed. The composition of the modern group of chironomid and diatom species is still different from the original fauna and flora observed in Wohlensee observed immediately after the dam was built, suggesting that the ecosystem has not (possibly not yet) recovered back to its original state, although the observed taxa indicate a similar water quality as at the initiation of the lake.

Influence of oceanographic conditions on multidecadal sea surface temperature variability reconstructed from molecular proxies during the Last Interglacial sapropel deposition

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Anthropogenic greenhouse gas forcing causes Mediterranean sea surface temperatures to increase at a faster rate than the global sea surface temperature, potentially leading to changes in oceanographic and environmental conditions that are unprecedented in the instrumental era. Thus, it is important to reconstruct climate-oceanographic interactions from past warmer-than-present periods, as partial analogs to future conditions.

The Last Interglacial (~129,000-116,000 years ago) is the most recent warmer-than-present period in Earth's history. Sapropel S5, deposited during this period, presents an excellent archive to study the high-resolution paleoclimate evolution of the Mediterranean region. We studied the S5 layer recovered in core M51/3-SL104 from the Pliny Trench region. This sapropel is varved for most of its extension and thus provides an opportunity to generate a precise relative age model.

We recently applied mass spectrometry imaging (MSI) to long-chain alkenones in order to reconstruct sea surface temperature (SST) changes during this period in annual to subdecadal resolution, and observed that the forcing of the SST was partly dependent on the oceanographic conditions. To provide a better understanding of the relation between SST and changes in oceanographic conditions, we here present MSI data from the same archive, but targeting an alternative SST proxy based on glycerol dialkyl glycerol tetraethers (GDGTs).

GDGTs are produced by planktonic archaea and are recognized as important biomarkers for paleoenvironmental studies. Changes in the relative abundance of GDGTs with different number of cycloalkyl rings is highly sensitive to ecological and environmental factors such as temperature and to a lesser extent nutrient concentration. Nevertheless, under the highly stratified nutrient-rich conditions prevailing during the Mediterranean sapropel S5 deposition, marine Thaumarchaeota may have resided at the chemocline and thus recorded a signal that is not representative of SST. In this poster, we will compare ultra-high resolution GDGT-based and alkenone-based SST records to obtain information about how ocean circulation influences SST reconstructions during sapropel S5 deposition. To do so, we will explore the variability and phase relationship between two different SST records in multidecadal to multicentennial time bands.

Early-mid Holocene hydroclimate records using stable carbon and oxygen isotopes of shallow marine benthic foraminifera from Singapore

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Stable carbon (δ^{13}C) and oxygen (δ^{18}O) isotopes in carbonate from foraminifera are commonly used as a palaeoenvironmental proxy in Quaternary records. Here, we present high-resolution stable isotopic records from ~ 8.8 to 5.8 cal ka BP from the Kallang River Basin, Singapore. The records use three shallow benthic foraminifera species (*Ammonia* sp., *Elphidium* sp. and *Asterorotalia pulchella*). In equatorial coastal settings, the δ^{13}C value of foraminiferal carbonate is more representative of environmental variability, as high rates of evaporation (E/P) in the equatorial region can mask the δ^{18}O signals of rainfall changes. Our foraminiferal δ^{13}C records generally exhibit an increasing trend that follows Equatorial boreal summer insolation. Enrichment of the *A. pulchella* δ^{13}C values between 8.3 and 8.1 cal ka BP may indicate a drying period likely related to the 8.2 ka climate anomaly. Our work demonstrates that *Elphidium* sp. and *A. pulchella* may be more suitable candidates for environmental reconstruction in equatorial regions, as vital and microhabitat effects may mask the sensitivity of *Ammonia* sp. to environmental changes.

Ostracoda as proxies in sediments of subrosion depressions in Germany

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Subrosion is a common phenomenon in Central Germany and other regions. Subsurface evaporites of mainly Permian (Zechstein) and Triassic age are dissolved by groundwater. If the cavities created by this process collapse a crater-like structure can be formed at the surface, sometimes with dimensions of kilometres but mostly much smaller. Those depressions are regularly filled with water and act as sediment traps. Middle and Old Pleistocene sediments of Germany are often preserved in such subrosion depressions and provide important palaeoclimate archives.

Ostracoda are minute Crustacea with a calctitic bivalved carapace. The shells of such a carapace are easily fossilisable and appreciated as archives of palaeoenvironmental conditions and processes as well as index fossils for their stratigraphical age. They can be used in palaeoecological association analyses and shell chemistry approaches. The high diversity and often high abundance of ostracods highlight them as one of the most significant microfossil groups of Quaternary sediments.

The 197 Quaternary ostracod species reported by Fuhrmann (2013) for Central Germany contain 51 biostratigraphical index species allowing dating in a resolution of interglacial and glacial periods. Many taxa are palaeoclimatic indicators. Index species and the Mutual Ostracod Temperature Range method are the most used tools beside stable isotope analysis on ostracod shells for reconstructing summer and winter temperatures. A special phenomenon is the occurrence of marginal marine ostracod taxa in inland water bodies indicating elevated salinity. Examples are *Cyprideis torosa* and *Cytheromorpha fuscata* occurring in slightly saline lakes of Central Germany. Transfer functions enable quantitative salinity reconstructions indicating brine extrusion and a low precipitation/evaporation balance.

We present case studies of the application of Quaternary ostracods from subrosion depressions for showing their high value for indicating stratigraphical age and glacial-interglacial cycles, elevated salinity as result of protruding brines during active subrosion processes, size and structure of water bodies and aquatic habitats, as well as biogeographic relations. The study areas shown lay in Thuringia, Saxony-Anhalt and Nordrhein-Westfalia.

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A 225-year gapless record from Lake Khamra based on diatom oxygen isotopes, diatom assemblages and biogeochemical analyses: Reconstructing hydroclimate extreme events in Siberia

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The northern landscapes are highly affected by global climate warming, but little is known about associated changes in hydrology. Recent drought events resulted in higher salinities of permafrost-affected lake systems, a major threat to local freshwater resources. The overall goal of this project is to understand the relationship between climate warming, hydrological extremes and water quality both in pristine and human-influenced lake systems in northeastern Siberia on decadal time-scales. The temporal focus is on the Early Holocene warming phase and the recent climate change to disentangle the natural and anthropogenic contributions.

Here we present a first high-resolution dataset of Lake Khamra (59.99° N, 112.98° E) located in south-west Yakutia, in a remote permafrost area in Russia. Established from a Pb/Cs dated sediment shortcore, a 225-years (2018 – ca. 1790 CE), gapless stable oxygen isotope record of diatoms ($\delta^{18}O_{diatom}$) is analysed to explore whether hydroclimatic extreme events in Yakutia became more frequent during current warming. Recent stable water isotope data of Lake Khamra allowed for a calculation of oxygen isotope fractionation between diatomaceous silica and lake water supporting the $\delta^{18}O_{diatom}$ measurements. Diatom assemblages from the same sample material help reconstructing changes in the lake's hydrochemistry, their timing and amplitude in relation to the $\delta^{18}O_{diatom}$ record. Biogeochemical analyses provide an insight into the changes in the lake system with regard to recent climate change and increasing human influence. An indication of industrial pollution can already be seen by the tripling of mercury levels throughout the record with a marked increase from the 1930s onwards. Meteorological data and other proxy climate records from the region are used to identify hydroclimate extreme events and find common driving mechanisms.

We present a new hydroclimate proxy record for an area with a great demand of paleohydrological data. The project will gain substantial knowledge for research on hydroclimate feedbacks to recent global warming to better assess potential risks for local water resources.

Holocene littoral molluscan assemblages from Uruguay: geochronology, paleoecology and paleoenvironmental reconstruction

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Holocene marine fossiliferous beds from Uruguay allow the reconstruction of the biotic and paleoenvironmental conditions in mid latitudes of the southwestern Atlantic Ocean during the present interglacial. The deposits crop out in a thin strip along the coast which enables a paleoecological/paleoenvironmental comparison with the current conditions that develop in each geographic sector of the Río Uruguay-Río de la Plata-Atlantic Ocean west to east gradient. An ongoing project aims to expand the geochronologic and molluscan database to refine the paleoenvironmental reconstructions in different time slices. We incorporated about 30 AMS shell datings which mostly fall within the previously known age range for the Holocene marine molluscan assemblages, but we also obtained some new slightly older ages circa 7000 ^{14}C yrs BP. The oldest Northgrippian ages (from 7500 to 6000 cal yrs BP) correspond to dark clayey deposits with shells frequently preserved in life position. Assemblages are dominated by *Heleobia* spp., followed by *Ostrea stentina*, *Anomalocardia flexuosa* (marine euryhaline species). The youngest Northgrippian (6000 to 4200 cal yrs BP) are similar but include a better representation of the euryhaline *Mactra isabelleana*. This species and the estuarine *Erodona mactroides* predominate in the sandy deposits in the W and S-SE area of the Uruguayan coast. The oldest Meghalayan sandy deposits (4100 to 3000 cal yrs BP) from the W sector are dominated by *E. mactroides* with a scarce representation of *M. isabelleana*. The youngest Meghalayan assemblages (3000 to 1000 cal yrs BP) crop out mainly in the E sector. The sandy deposits are dominated by *M. isabelleana* or *Glycymeris longior*, and in the very fine grain lagoon deposits *H. australis* and *E. mactroides* predominate. The molluscan distribution pattern indicates higher salinity conditions in all the time slices analyzed towards the current fluvial and estuarine settings influenced by the Río Uruguay and inner Río de la Plata. Also, a higher temperature than present is supported by the record of warm extralimital species better represented in the oldest Holocene assemblages but still recorded in very young ones. This is a contribution to the research grant ANII FCE_1_2021_1_167109 and PEDECIBA Geociencias.

Holocene sedimentation in the southern Red Sea continental shelf controlled by monsoon dynamics and basin geometry

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The shallow continental shelfs of the semi-enclosed Red Sea basin are regarded as excellent recorders of global sea-level and regional precession-driven climatic fluctuations. Sedimentation within the southern sector of the basin is strongly influenced by the winter and summer modes of the South Asian monsoon system, which impacts both terrestrial and marine processes. Moreover, the sedimentation of the submerged southern Red Sea shelf is influenced by a complex geomorphological configuration resulting from tectonic processes, such as salt diapirism, and the subsequent dissolution of evaporitic domes creating deep sinkholes along the shelf. To gain insight into the southern Red Sea Holocene monsoon dynamics and the effects of basin geometry on biotic and abiotic processes, we have generated a multi-proxy record from a deep sinkhole located within the inner shelf of the Farasan Archipelago. Our decadal- to centennial-scale resolution geochemical (X-ray fluorescence core scanning), mineralogical, sedimentological (grain sizes) and micropaleontological (planktic and benthic foraminifera) datasets are compared to a marine record from the outer continental shelf at a similar geographical latitude, in order to explore the controls of topography on sedimentation. Multivariate statistical analysis of our data provides a clear distinction between three chronostratigraphic intervals. Combined reconstructions of submerged paleoshorelines with both planktic and benthic foraminiferal assemblages suggest that early Holocene (9.8–8.7 ka BP) sedimentation is controlled by a restricted connection with the open sea and the development of suboxic conditions. The mid-Holocene (8.7–4.2 ka BP) reveals an increase in marine productivity, which we link to the strengthening of the south west monsoon (SWM). On the contrary an increase in fined grained aeolian inputs during the late Holocene (4.2 ka BP–recent) points to a strengthening of the north east monsoon (NEM). All in all, our record proves to be a sensitive recorder of South Asian monsoon changes on centennial timescales in the southern Red Sea. We conclude that the lag in the development of a fully marine state at our site can be attributed to the complicated topographical features of the inner shelf while the geometry of the sinkholes controls the boundary conditions for the local marine ecosystem.

Spatially diverse hydroclimatic response to the 4.2 ka event in the Asian monsoon region

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The 4.2 ka event was a widespread abrupt cooling event in the Northern Hemisphere. However, there was a spatially inconsistent hydroclimatic response to the 4.2 ka event in the Asian monsoon region. To further characterize and to determine the origin of this phenomenon, we present a pollen record spanning the interval from 10.7 ka to the present from a subalpine lake in the Hengduan Mountains, southwestern China, which are climatically influenced by the Indian monsoon; and we then reconstruct the spatial pattern of the hydroclimatic response to the 4.2 ka event across the Asian monsoon region, based on a synthesis of our own and previously published data. The results reveal the following. (i) During the interval of 4.5–3.9 ka (spanning the 4.2 ka event) in the subtropical mountains there were abrupt decreases in evergreen broadleaved trees, including evergreen *Quercus*, *Castanopsis* and *Cyclobalanopsis*. (ii) The hydroclimatic response to the 4.2 ka event across the Asian monsoon region was characterized by a tripolar precipitation pattern, with decreased rainfall over India and southwestern and northern China, and increased rainfall over central China. Therefore, we conclude that the hydroclimatic response to the 4.2 ka event in the Asian monsoon region was spatially heterogenous, which we argue was related to the slowdown of the Atlantic Meridional Overturning Circulation (AMOC). During the interval of 4.5–3.9 ka, cooling at high latitudes of the Northern Hemisphere, caused by AMOC weakening, led to the southward movement of the Intertropical Convergence Zone (ITCZ), which resulted in decreased rainfall over most of the Asian monsoon region. The wet conditions in central China may have been modulated by the southward movement of the westerlies, which was also caused by the cooling at northern high latitudes. The southward displacement of the westerlies restricted the northward penetration of the monsoonal air flow, and thus the monsoon rainbelt stagnated over central China, where there was a corresponding increase in precipitation.

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Holocene stages in the North-Western Europe: lake sediments archives

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We compared the formal subdivision of the Holocene into the Greenlandian, Northgrippian and Meghalayan stages/ages (Walker et al., 2012); subdivision of the Blytt–Sernander scheme; archaeological periods, the pollen inferred temperature curve and Baltic Sea stages for the North-Western Europe. The comparative analysis showed that the events 8.2 and 4.2 are not traced throughout the entire territory of the North-Western Europe. According to the Blitt-Sernander scheme subdivision of the Holocene are distinguished in the North-Western Europe everywhere. Good stratotypes in this case are sediments sequences of small lakes. At the same time, pollen data must necessarily be supported by the results of studies using the maximum set of other methods. We have original data of the transect from north to south for the North-West Russia. The lakes of the Kola Peninsula, Karelia, the Karelian Isthmus, the Valdai Upland and others regions were studied using a complex paleolimnological method with radiocarbon dating. The comparison of this data with those in the North-Western Europe lake sediments sequences and with existing regional schemes (Borzenkova et al., 2015; Hang et al., 2020; Wastegård, 2022) are make it possible to clarify the Holocene stages of over a large area of North-Western Europe. The region under study is united by the presence of lakes, which in their origin are associated with the last ice sheet. The stages of their development are similar to all synchronous changes in the natural environment. In the last time also we have obtained new results of the lacustrine sediments sequences from the North-West Russia with radiocarbon dating for the Pleistocene-Holocene boundary which allowed us to confirm the periods boundaries of warming and cooling: two Dryas Stadials and two Bølling and Allerød Interstadials.

Lakes history and environmental changes in the Lesser Caucasus: a case study of the lakes at the Aragats massif

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The volcanic massif Aragats (4090.5 m a.s.l) is the most elevated part of Armenian plateau. Lots of small lakes are situated on Aragats, mostly between 2900 m and 3500 m a.s.l. We obtained new paleolimnological (lithology, radiocarbon dating, geochemistry, pollen, diatoms) and geomorphological survey data of the Aragats largest lakes, glacial (moraine-dammed) Lake Kari (3187 m a.s.l.; southern slope) and Lake Umroi (3050 m a.s.l.; eastern slope). The studied lakes formed during the Holocene. The first radiocarbon (AMS) dating of lake sediments in the Lesser Caucasus high-mountain lakes combined with pollen analysis could be taken as the most representative approach for indirect identification of the age of adjacent moraine deposits and for studying the rhythmic variability of environmental processes during the Holocene. The sediments of Lake Kari formed during the last 4000 years, and in Lake Umroi – for about 8000 years. The sedimentation rate in the Armenian high-mountain lakes is low; however it varied significantly in different periods of lakes history. According to paleolimnological data from Lake Kari and Lake Umroi, we recorded a period of warming and humidification of the climate around 3000-2000 cal. BP. This was a period of extensive development of forests and the shift of the forest boundary to its present elevation. Our results also indicate a reduction of mountain glaciers about 3000 years BP and subsequent cooling with the onset of new glaciation about 2000 years BP. We compare our results of the high mountain lakes with the available data on the mires (Cromartie et al., 2020) and archaeological sites of Aragats. At the foot of the massif Aragats in the steppe landscapes (about 2000 m a.s.l.) the archaeological investigations (Smith et al., 2009) recorded the archaeological sites dated from the Neolithic to the present day.

Mid and Late-Holocene palaeoenvironmental and land-use changes in NE Crimea based on a sediment record from Lake Chokrak

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In this study, a sediment core from Lake Chokrak, NE Crimea, was investigated to reconstruct the evolution history of Lake Chokrak and vegetation changes around the lake, as well as climate variations, recorded both in geochemical and palaeoecological proxies. The recovered deposits were subjected to bulk carbon and nitrogen, XRF, and palynological analyses. Between 7700 and 6900 cal yr BP a relatively shallow marine bay existed in the area of Lake Chokrak. During this period, steppe vegetation around the bay was dominated by mesic herbaceous communities, whereas in the Crimean mountains the expansion of broadleaved forests occurred. A transgressive stage is observed from 6900 to 6400 cal yr BP when the water level increased and finer sediments accumulated in the basin. Between 6400 and 6200 cal yr BP an aridity event led to a decrease in water level and precipitation of evaporites. Starting from 6200 cal yr BP, a renewed transgressive stage is observed with increased water level, accumulation of fine-grained sediments and precipitation of carbonates. Wetter conditions were revealed between 5400 and 5000 cal yr BP, when the terrigenous influx into the bay increased and meadow steppe spread around the site. After 5000 cal yr BP more arid conditions prevailed in the region with increased precipitation of evaporites and the expansion of grass steppe. The infilling of the basin and formation of the sandbar started around 3000 cal yr BP when clay sediments intermixed with sand layers and the steppe vegetation became more xeric. A transitional stage from semi-open to closed basin lasted from 1400 to 800 cal yr BP and is characterised by precipitation of evaporites and disappearance of molluscs. The current stage (from 800 cal yr BP to present) of the closed lake basin is marked by sediment lamination, intensive precipitation of salts, and complete absence of molluscs due to high salinity of the brine. Human impact on the vegetation was first recorded around 3500 cal yr BP by the emergence of agriculture in the region and further intensified after 700 BCE with the appearance of Greek settlements near the site.

Climate changes during the Lateglacial in South Europe: new insights based on pollen and brGDGTs of Lake Matese in Italy

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The Lateglacial (14,700-11,700 cal BP) is a key climate period marked by rapid but contrasted changes in the Northern Hemisphere. Indeed, regional climate differences have been evidenced during the Lateglacial in Europe and the Northern Mediterranean areas. However, past climate patterns are still debated since temperature and precipitation changes are poorly investigated towards the lower European latitudes. Lake Matese in Southern Italy is a key site in the Central Mediterranean to investigate climate patterns during the Lateglacial. This study aims to reconstruct climate changes and their impacts at Matese using a multi-proxy approach including magnetic susceptibility, geochemistry (XRF core scanning), pollen data and molecular biomarkers like branched Glycerol Dialkyl Glycerol Tetraethers (brGDGTs). Palaeotemperatures and -precipitation patterns are quantitatively inferred from pollen assemblages (multi-method approach: Modern Analogue Technique, Weighted Averaging Partial Least Squares regression, Random Forest, and Boosted Regression Trees) and brGDGTs calibrations. The results are compared to a latitudinal selection of regional climate reconstructions in Italy to better understand climate processes in Europe and in the circum-Mediterranean region. A warm Bølling–Allerød and a marked cold Younger Dryas are revealed in all climate reconstructions inferred from various proxies (chironomids, ostracods, speleothems, pollen, brGDGTs), showing no latitudinal differences in terms of temperatures across Italy. During the Bølling–Allerød, no significant changes in terms of precipitation are recorded, however, a contrasted pattern is visible during the Younger Dryas. Slightly wetter conditions are recorded south of latitude 42°N whereas dry conditions are recorded north of latitude 42°N. During the Younger Dryas, cold conditions can be attributed to the southward position of North Atlantic sea-ice and of the Polar Frontal JetStream whereas the increase of precipitation is Southern Italy seems to be linked to relocation of Atlantic storm tracks into the Mediterranean, induced by the Fennoscandian ice sheet and the North European Plain. By contrast, during the Bølling–Allerød warm conditions can be linked to the northward position of North Atlantic sea-ice and of the Polar Frontal JetStream.

Palaeoenvironmental changes in the Iberian central system during the Late-glacial and Holocene as inferred from geochemical data: A case study of the Navamuño depression in western Spain

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The Iberian Central System (ICS) is a clue region to reveal Mediterranean/Atlantic inferences over Iberia. We present a multidisciplinary study from western Spain conducted in the Navamuno depression (ND), covering the last 16.8 ka (cal BP). A reconstruction of the palaeotemperature from the resulting geochemical data highlights four cold and dry intervals, namely, the Oldest Dryas, Older Dryas, Intra-Allerød Cold Period (IACP), and the Younger Dryas, along with warmer intervals: the Bølling (14.7–14 ka) and the Allerød (12.9–12.6 ka); however, the Greenland Interstadial GI-1c (13.4–13.1 ka) is barely distinguishable in the ND. Despite the shortage of biomass to sustain fire, the earliest charcoals are from ~14.4–13.8 ka. Evidence of ash/dust events overprinting the geochemical background starts at ~13.8–12.8 ka. Significant fire activity in the Early Holocene at ~11.7–10.6 ka affected the ND, matching the westernmost ICS data. This period includes short oceanic spells inferred from Cl peaks at ~10.9–10.2 ka, and three cold intervals at 11.4, 9.3, and 8.2 ka disrupted the progressive temperature increase. The Mid-Holocene showed a continuously increasing trend towards an arid climate, peaking at 4.2 ka under a pervasive dust influx from North Africa, which has prevailed since almost ~7.9 ka. A prominent volcanic ash event at ~6.8–5.8 ka in Navamuño is identified from a heavy metal-rich layer, synchronous with the last known eruption of the Calatrava volcanic field (South-Central Spain; affecting even northern Spain (Rozañas). This volcanic eruption could affect many other regions half north of Iberia. The pervasive presence of oceanic aerosols in the last three millennia (2.8 ka ~) allowed the formation of a Cl-rich peat layer during the Ibero-Roman humid period ~2.1 ka, before a changing around ~0.4 ka toward colder and drier conditions at the Little Ice Age (LIA) period.

PAGES Human Traces Pb sediment records project: creating a community database of published Holocene Pb pollution records

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A mismatch between Greenland ice core data and European lake sediment records of millennial-scale atmospheric Pb deposition has prompted a fresh look at spatial variations in Pb pollution signals, with an emphasis on distinguishing global from regional synchronous events. The PAGES (PAst Global changES) Human Traces working group is leading the creation of a global community database of published Holocene Pb records in peat and lake sediments to address this and other unanswered research questions on global lead pollution. In this talk we introduce the database, explain the parameters for record inclusion, and present preliminary findings. We confirm that some episodes of Pb enrichment found in the Greenland Ice records, particularly those dated to late 9th century CE, are absent from European records indicating substantial transport of atmospheric Pb pollution from more distant sources in Asia with distinctly different histories of metal working. We also explore the extent to which Roman Pb pollution constitutes a global signal. The implications of this for our understanding of pollution pathways at local, regional, and global scales is discussed. This work is presented on behalf of the Human Traces Pb records sub-working group.

A molecular multiproxy record from Sumatra indicates continuous Holocene warming but a mid-Holocene rainfall maximum

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The maritime continent (MC) forms the central part of the Indo-Pacific Warm Pool (IPWP),. This tropical region is a critical component of the global climate system by providing large amounts of latent heat to the higher latitudes via deep atmospheric convection. Paleoclimate information remains relatively scarce from the MC despite its global importance, calling for additional records from the region. We generated a multisite-multiproxy record from Sumatra, with a main focus on the glycerol dialkyl glycerol tetraether (GDGT) distributions allowing the use of the MBT'5me as a paleothermometer proxy, and compared the results also with pure lake samples and a soil transect. We investigated one homogenous peat core and one paludified lake (now peat). The GDGT sources in the former remained constant, allowing a robust temperature reconstruction that shows gradual warming during the last 8 ka, including a plateau 3-5 kyr BP. Comparison of the GDGTs with other information like bulk density and mineral content of the paludified lake record led to the conclusion that these were mainly influenced by their provenance (soil, lake, peat) rendering this record unsuitable for temperature reconstruction, but allowing environmental reconstruction.

The finding of ongoing warming over the past 8 ka agrees with several climate model simulations for Sumatra and nearby marine SST reconstructions from the Indian Ocean (western IPWP). This trend is opposite to previous marine reconstructions in the eastern IPWP, which may be related to long-term changes in the Walker circulation. Of note is that there is little to no seasonal bias in our equatorial peatland site and bacterial lipid source, something that has been implicated as biasing temperature proxies.

Leaf wax hydrogen isotopes of both records, supported by bulk, chemical and other molecular proxies, indicate an increasingly humid Holocene with a maximum between 4-6 kyr BP, suggesting that export of heat and moisture from the IPWP to the rest of the globe was at its strongest in this period. We find a decline in precipitation strength that is coincident with the reorganization and general drying and cooling of global climate at the start of the Meghalayan age.

Midges through the ages - Chironomidae in Eemian and early Weichselian palaeolake sediments from Bispingen, northern Germany

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Investigating past climatic changes is crucial to understand the nature of present human impact on climate and environment. In this context, inferring past ecological conditions from the analysis of non-biting midges (Chironomidae) can bring us closer to the explanation of the nature of present climate change. The analysis of subfossil Chironomidae remains in lake sediments thereby offers the unique opportunity to reconstruct several important environmental parameters, including past trophic status and pH value of lakes as well as the average summer palaeotemperature. Nevertheless, not many high-resolution palaeoenvironmental reconstructions have been conducted on the basis of subfossil Chironomidae remains for the Eemian interglacial and early Weichselian glacial so far, periods that were characterized by distinct climatic changes but absent human impact. The present study is part of a larger project that applies a multi-proxy approach to the partially annually laminated sediments of the Eemian paleolake of Bispingen in northern Germany. The Eemian and Early Weichselian section of Bispingen core consists respectively of diatomitic, calcitic-diatomitic and clastic-organic material with either faint or fine lamination and was sampled with high resolution. This research layer is about 12 meters thick. Microscopic chironomid identification was carried out using identification keys, e.g. Brooks et al. (2007), Cranston (1982) and Vallenduuk (2007). Here we present first results of the analysis of subfossil Chironomidae remains, aiming at determining temperature changes during the Eemian and early Weichselian and the climatic gradient between northern and southern Europe. Supported by geochemical and palynological data, the main aim of the presented research was conducting palaeoecological analyses using subfossil Chironomidae remains and reconstructing past summer air temperature. In the final effect, some distinct phases were extracted, providing information about trophy and thermal conditions during the Eemian interglacial and early Weichselian glacial.

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Holocene Emiliania huxleyi and Braarudosphaera bigelowii blooms and abundance variations in Quaternary sediments of the Western Black Sea shelf

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During the Holocene, the most important groups of primary marine plankton producers are the unicellular algae, especially the calcareous nannoplankton. In the NW Black Sea, the calcareous nannoplankton assemblages consists of *Emiliania huxleyi* and *Braarudosphaera bigelowii*. Nowadays, *Emiliania huxleyi* is found at the surface-waters of the Sea of Azov at approximately 11‰ salinity, but also in the Red Sea at salinity up to 41‰. The opportunistic *Braarudosphaera bigelowii* species is also present in the Red Sea, but not in the Sea of Azov. The minimum salinity where *Braarudosphaera bigelowii* is found is approximately 17‰, in the Black Sea.

Several cores have been collected from the NW Black Sea and have been detailed studied for the calcareous nannoplankton fluctuation. The abundance pattern of *Emiliania huxleyi* and *Braarudosphaera bigelowii*, the only two species present in the Holocene deposits of the NW Black Sea, mirrored the Late Pleistocene to Holocene paleoenvironmental changes, linked to the shift of the Black Sea from a giant lake, during its isolation in the LGM (Last Glacial Maximum) to a marine basin, after the reconnection with the Mediterranean.
As expected, our finding indicates that the Unit 3 (= the Lacustrine lutite) was deposited in a freshwater environment, overlapping the restricted water circulation interval („lake" phase) of the Black Sea. During the deposition of Unit 3, the salinity in the Black Sea was most probably lower than 11‰, which is also the minimum salinity tolerated by *Emiliania huxleyi*, so no *in situ* calcareous nannoplanton species occur. *Emiliania huxleyi* already occur in several cores at the top of Unit 3 (Lacustrine Lutite), while a persistent occurrence of both *Emiliania huxleyi* and *Braarudosphaera bigelowii* in the Unit 2 (Sapropel Mud) suggests a sharp water salinity increase above 17 ‰. In Unit 1 (Coccolith Mud), blooms of both *Emiliania huxleyi* and *Braarudosphaera bigelowii* have been recorded. Generally, the fluctuation pattern of *Braarudosphaera bigelowii* is negatively correlated with the *Emiliania huxleyi* one. In conclusion, a stable marine regime of the Black Sea basin during the depositional interval of Units 1 and 2 may be assumed.

Nature and humans in Serteya region - symbiosis or competition? A paleoecological perspective on 9000 years

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The qualitative and quantitative analyses of subfossil invertebrates help to reconstruct the trends in changes of the past environment. Here we present palaeoecological studies of the human settlement and its environmental background in the Serteya region. It is an area located in the Vitebsk Lake District in the western part of the Russia. Since the late Palaeolithic times it has been attractive for human settlement, especially hunter-gatherers. Based on the results of palaeoenvironmental proxies, we can learn about the factors that could have been driving prehistoric settlers. During the ten-year study, eight biogenic sediment cores were studied: seven cores from the Serteya II archaeological site and one core from the nearby kettle hole. The study included the analysis of Chironomidae communities (cores ST IIa, STII M25, and STII L29), analyses of Chironomidae and Cladocera (KH, STP I and STP II) and Coleoptera (STII N24 and STII L22). The analyses were performed with high resolution (1 cm - 5 cm). The obtained results made it possible to reconstruct in detail the palaeoecological changes taking place in the Serteya region at the end of the last glaciation and throughout the Holocene. Reconstructions of climatic conditions were inferred with Chironomidae, Cladocera and Coleoptera subfossil communities. The obtained data were supplemented with the results of palaeobotanical analyses. The age-depth models of the cores are based on geochronometric and AMS radiocarbon dating. The performed palaeozoological and palaeobotanical analyses illustrated conditions of Neolithic communities settlement, their functioning and the way they impacted lake trophic state and its catchment landcape.
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Multi-proxy analyses and synchronization of European palaeoclimate records from the Holsteinian interglacial (MIS 11c)

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Abrupt climate oscillations are important features of natural climate variability. Nevertheless, given the substantial anthropogenic climate impact during the Holocene, disentangling between natural climate variability and superimposed human influences, especially with respect to the rates of climate change, still poses a major challenge. In this context, investigating natural climate variability and associated environmental changes during past warm periods can provide important information about the range and rates of natural climate fluctuations. This can in turn allow to assess the present level of anthropogenic interference in the context of progressive global warming. Among the most recent warm periods in Earth's history, the Holsteinian interglacial (~400,000 years ago; the terrestrial equivalent of Marine Isotope Stage (MIS) 11c in Central Europe) represents a particularly well-suited reference interval for studying natural climate variability under interglacial boundary conditions as it was characterized by a similar orbital configuration as the Holocene but lacked any notable anthropogenic climate impact. As known from previous studies, the Holsteinian interglacial was interrupted by two distinct centennial-scale cold periods, the so-called Older and Younger Holsteinian oscillations. However, the drivers and spatio-temporal patterns of these cold intervals have so far remained elusive. To improve the understanding of these rapid climate fluctuations, particularly with respect to (1) their characteristics, spatial extent and synchroneity across Europe and (2) the succession of associated environmental changes, two annually laminated (varved) palaeolake sequences from eastern Poland (Ossówka) and northwestern Germany (Dethlingen) will be analysed within the presented project by using a multi-proxy approach. Besides establishing robust internal chronologies through microscopic varve counting, parallelization of both sediment records will be facilitated by cosmogenic radionuclide (^{10}Be) measurements. In addition, high-resolution analyses of terrestrial and aquatic microfossils (pollen, diatoms, chironomids, cladocerans), geochemical parameters (X-ray fluorescence core scanning) and the stable isotope composition of terrestrial biomarkers will be carried out. These will allow to reconstruct the spatio-temporal characteristics of the environmental responses to the two rapid climatic fluctuations during the Holsteinian interglacial and ultimately yield a better understanding of the pace and range of natural interglacial climate variability.

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Environmental changes during the last millenniums in Barents Sea: multiproxy evidences

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Atlantification is the increasing influence of the warmer and saltier Atlantic water in the Arctic Ocean. The Barents Sea is a key for the comprehension of the northern hemisphere oceanic circulation through its sensitive shallow water polar ecosystem, related to (1) the oscillating ice edge link to the Artic Water (ArW) and (2) the recent expansion of the warmer Atlantic Water (AW) into the region. Understanding the past variability of this "Atlantification" is thus crucial in providing a longer perspective on the current global change. In this sense, we reconstruct the paleoenvironmental and climate history from the core HH1141, located at 74.0155°N 21.0711°E collected at -285 m depth, during the late Holocene using benthic foraminiferal assemblages, stable isotopes analyses ($\delta^{13}C$ and $\delta^{18}O$), sedimentological studies and sea ice proxies (IP25). Based on radiocarbon analyses on carbonate tests, the sediment core encompasses ca. the last 3000 yrs BP. Preliminary results indicate that, at the base of the core, the relative dominance of *Islandiella sp*, *Cassidulina reniforme*, *Ephidium* sp. and *Cibicides lobatulus*, species associated with cold bottom water mass. Towards the top of the core, the foraminiferal content is characterised by the occurrence of *Nonionella labradorica, Trifarina angulosa, Stainforthia* sp., *Adercotryma glomeratum* and *Melonis barleanus,* taxa commonly related to the AW mass influence showing increasing temperatures. The sediment sequence is dominated by the fine fraction (i.e. silt) and clay, but sand content increases towards the top, and the presence of clasts (> 5 mm) is observed. We will couple data on foraminiferal assemblages with new data on $\delta^{18}O$ and $\delta^{13}C$ of foraminiferal tests and organic proxies to resolve the environmental changes associated with the late Holocene sea ice retreat, change in productivity and water mass properties. Finally, we will compare our results with other areas within the Barents Sea covering the same period to resolve the regional pattern and place the modern Atlantification into a larger context of natural climate variability.

Past changes in atmospheric circulation and precipitation source in eastern South Africa, based on combined pollen and sedimentary leaf-wax δD records

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Proxy-based climate reconstructions from Southern Africa are still limited in both quality and quantity, and expanded data on regional hydroclimate is central for better assessments of climate change. South Africa is representing a key area in this respect, as its hydroclimate conditions are sensitive to latitudinal and longitudinal fluxes in circulation systems, e.g. the spatiotemporal interplay between the temperate westerlies and tropical easterlies. In this study we reconstruct hydroclimate and vegetation in eastern South Africa, by analyzing sediment cores from two ecologically stable but hydrologically sensitive wetlands (Braamhoek wetland, Dartmoor Vlei). The sediment cores span the last ca 15 000 and 24 000 cal yrs BP respectively. Both sites are located between 28 and 32°S, a latitudinal zone identified as sensitive to large scale atmospheric shifts between westerly and easterly air-masses. Applied proxies include hydrogen isotope composition (δD) in sedimentary fossil *n*-alkanes (leaf waxes) from both sites, and a new fossil pollen record from Dartmoor Vlei. The leaf wax δD co-varies between sites, suggesting an external, region-wide, probably climatic driver dictating the isotopic shifts. This is interpreted to reflect changes in moisture source area, indirectly also related to temperature and precipitation characteristics. Lower leaf wax dD between ca. 14 000 and 11 500 cal yrs B, as well as from 8 500 cal yrs BP onwards, reflect periods of cooler and drier conditions associated with D-depleted air masses from the Atlantic and Southern Ocean. High δD-values during the early Holocene (ca. 11000 - 8 500 cal yrs BP) indicate wetter and warmer conditions associated with isotopically enriched air masses from the Indian Ocean (easterlies). The Dartmoor pollen record generally support this pattern, when applying the variability of the Asteraceae to Poaceae pollen ratio which is considered a vegetation proxy for rainfall seasonality in this region. Overall, the long-term proxy evidences are in agreement with paleo-records from e.g. Antarctica and eastern equatorial Africa suggesting their variability is driven by periodic latitudinal expansions and retreat of the circumpolar circulation systems and Intertropical Convergence Zone as a response to orbital and oceanic forcing.

Summer climate variability in the Eastern Carpathians during the last millennium: a multiproxy approch

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Eastern Europe lies at contact between continental and oceanic climatic influences, with hot and dry summers and is also influenced by northward expanding Mediterranean climate, being thus especially sensitive to forecasted changes in the strength and intensity of summer heat waves. Understanding the past dynamics of summer climate variability is thus of paramount importance in our quest to mitigate and/or adapt to ongoing climatic changes.

In this context, we present and discuss here droughts and temperature changes in the heart of Eastern Europe (Transylvanian Basin and Eastern Carpathian Mountains) during the last 1000 years, through the analysis of documentary and proxy-based data.

Our historical analysis show that summers over the last millennium were characterized by three dry periods (AD 1100-1150, 1400-1750, 1750-1900). Climate in Eastern Europe during the last millennium was complex, with wet and warm conditions during Early Medieval Warm Period (MWP, AD 850 - 1100) followed by dry condition during the Late MWP (AD 1100 - 1150). The transition between the MWP and LIA periods (AD 1250 – 1400) is characterized by rainy and less dry periods. The most changes occurring during the Little Ice Age (LIA, AD 1400 – 1850), when the temperature drops and the occurrence rate of summer droughts show an increasing trend of ~ 0.3/season over the Eastern Carpathians. At the same time, the multiproxy analysis indicates a stability of the summer temperature in the last millennium, the variability being observed only for short periods.

The mechanism of the variability of temperature anomalies can be explained by the variations of the Sea Surface Temperature (SST) in the North Atlantic, so the prolonged periods of positive temperature anomalies during the summer are due to the warming of the SST, while the negative anomalies are due to the cooling of the SST.

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Vegetation of the last interglacial in central Italy

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Valle di Castiglione (Rome, central Italy) is an ancient volcanic lake, artificially dried out, belonging to the northern sector of Alban Hills. Valle di Castiglione is the oldest hydromagmatic crater of the Alban Hills, developed during the last stage of activity of the Tuscolano-Artemisio central edifice and characterized by pyroclastic flows and by final lava flows. The past lake is 1 km in diameter and occupies a phreatomagmatic explosion crater.
The lithostratigraphic sequence is characterized mostly by brownish black slightly calcareous muds, containing volcanic material, tuffities, gray calcareous muds with freshwater fauna. Today the area is characterized by a Mediterranean climate with rain mainly concentrated in autumn and winter and aridity during summer. The mean annual temperature is 15°C, the average annual rainfall is about 800 mm. The potential vegetation is Mediterranean, dominated by oaks, but the strong human presence in the area has deeply modified the natural vegetation The present study is linked to a larger project of INGV “AMusED” (https://progetti.ingv.it/it/amused) whose purpose is to investigate climate change with a multidisciplinary method in three sites in Italy, one of which is Valle di Castiglione (Roma). Here we present a new pollen diagram of the last interglacial (LI), the Eemian, corresponding to Marine Isotope Substage, MIS 5e, of marine stratigraphy.
A preliminary pollen diagram, with a time resolution of 500 years, was obtained from a composite core taken close to the lake depocenter. It depicted with continuity the vegetation history of LI near Rome, indicating that the environment was rather open (with mainly Poaceae, Cyperaceae, Amaranthaceae) and that mediterranean (mainly characterized by evergreen *Quercus*, Ericaceae and *Olea*) and mesophilous (mainly characterized by deciduous and semi-deciduous *Quercus*, *Carpinus betulus*, and Ulmaceae) forests alternated in dominating the vegetation.
We have to consider that Valle di Castiglione has a key role to understand the past in Central Italy, being an archive of information about past biodiversity, volcanic ash and tectonic activity.

The Holocene expression in humidity and sea surface temperatures in the western Mediterranean Sea

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The Mediterranean region is particularly sensitive to global climate variability that critically reflects on its hydrological conditions. A recently published high-resolution reconstruction of Holocene Sea Surface Temperature (SST) based on *Globigerina bulloides* Mg/Ca ratios set the basis to explore, within a warm climatic period, the impact of North Atlantic oceanographic conditions shaping the properties of the inflowing waters into the Mediterranean Sea. Going a step further in establishing the potential links between these oceanographical changes with the hydrological conditions on the southern Iberian Peninsula, we isotopically characterized (Sr, Nd and Pb) the present terrigenous sourcing and their transport processes on the Alboran Sea to use as an analogue to reconstruct the Holocene variations. The present-day isotopic characterization was performed of settling particles recovered by moored sediment traps under well-characterized meteorological conditions. This reveals that the main sources of the terrigenous particles arrive transported by the fluvial discharges around the Alboran Sea. Also, the observed isotopic changes during the recorded year were closely linked to rainfall patterns. Transferring this knowledge to the past time and compared with the SST, the results indicate that the most humid and warmer conditions were developed during the Early Holocene. Afterwards, a transition towards colder temperatures was linked with an aridification and enhancement of the torrential rainfalls, culminating with the coldest SST and higher torrential effect. During the Late Holocene, relative cold and drier conditions similar to the present were recorded.

Fluvio-estuarine sedimentation and estuarine evolution during the Late-Holocene in the upper Taw Estuary, England: unravelling the climate record of tidal river deposits.

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Present models of Holocene estuary evolution are driven largely by changes in relative sea-level (RSL) and other marine-realm boundary conditions, with less focus on long-term changes in fluvial regime and catchment climate. However, decadal-centennial scale climate change has been shown in fluvial studies to have a major control on Holocene river behaviour, with fluvial geomorphic records showing evidence for a high sensitivity in flood occurrence to changing climate and precipitation. It follows that the changes in river discharge associated with these climatic fluctuations should have an important bearing on inner estuarine hydrology and sedimentology. Indeed, some studies have shown that changes in freshwater inflow can be inferred by changes in estuarine palaeosalinity and that the timing of these events reflect changes in regional precipitation. Deposition in the transitional inner estuarine environment can therefore be seen to be controlled by both marine and fluvial influences, especially within tidal river environments. This gives the potential for tidal river deposits to provide both a record of catchment hydrology and regional precipitation, and a record of sea-level change.

The late-Holocene sedimentary record was investigated on both sides of the estuarine-fluvial boundary in the Taw Estuary, south-west England. The study aims to reconstruct regional climate based on changes in discharge-driven estuarine palaeosalinity. The diatom record of a comprehensive network of sediment cores enabled paleosalinity to be evaluated on both sides of the current tidal limit. The study also investigated the relative importance of changes in RSL and river discharge on estuarine sedimentation and centennial-scale geomorphic evolution. The fluvio-estuarine valley fill was split into a series of stratigraphic units, with a chronological framework derived using radiocarbon and OSL dating methods.

Geomorphic change in the inner estuarine zone is shown to be mainly influenced by phases of increased river discharge and catchment precipitation, with fluvial instability translating down river into the inner estuarine system. Changes in RSL during the late Holocene are also shown to influence inner estuarine sedimentation and geomorphic change, but to a lesser extent than centennial-scale climate-driven river discharge variability. A new late-Holocene multi-proxy climate record for the region is presented.

Tracking the Older Holsteinian Oscillation: a multi-proxy record from Eastern Poland

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Based on similarities with regard to orbital climate forcing, Marine Isotope Stage (MIS) 11c represents one of the closest astronomical climate analogues for the Holocene. Hence, insights into the climate variability of this interglacial can contribute to a better understanding of the present climate evolution and the natural climate drivers as it would occur without human interference.

The aim of the present study is to better understand the environmental variability during the MIS 11c. Therefore, eastern Poland as the area where the transition from maritime to continental conditions can be observed is an excellent region for this kind of palaeoenvironmental studies.

Lake sediments exposed in Ortel Królewski II (Eastern Poland) are characterized by a remarkable abundance of molluscs and ostracods, in many cases constituting over 70% of the deposits. The reconstruction of the paleoenvironmental conditions was possible using a multi-proxy analysis on the lake sediments from the Ortel Królewski II site. The high-resolution analysis covered the uppermost part of the profile, representing the so called pre-optimal part of the interglacial, namely the *Taxus* and *Pinus-Larix* pollen zones. High-resolution faunal analyses (ostracods and molluscs) combined with pollen, stable isotope and lithological analyses enabled detailed reconstruction of the rapid climatic fluctuations during the Holsteinian interglacial

While during the *Taxus* zone the temperature was rather stable, the short cooling event was documented in the beginning of the *Pinus-Larix* zone. The higher numbers of some cold-loving ostracods (*Candona candida*, *Candona neglecta* and *Fabaeformiscandona protzi*) indicate some deterioration of thermal conditions, which was additionally confirmed by the mutual ostracod temperature range (MOTR) method and the isotope record of ostracod carapaces. Additionally, lake level drop and expansion of reed zones within the *Pinus-Larix* pollen zone are inferred from the increased abundance of shallow water ostracod and mollusc species as well as increased $\delta^{13}C$ values. The short cooling event documented early in the *Pinus-Larix* zone in the studied profile might be an equivalent to the mid-MIS 11c cooling, the so-called Older Holsteinian Oscillation. Thus, by comparing this data with other sites from area nearby will hopefully allow to determine the spatial range of this climatic oscillation.

Further challenges for Pleistocene palaeogeography of the Middle Dnieper basin recorded in loess-glacial sediments

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Middle Dnieper loess-palaeosol sequences (up to 50 m thick) are considered as valuable long-term geoarchives of climate and environmental change during the Middle-Late Pleistocene. Their sedimentary record undoubtedly has a high correlative potential also due to the presence of the sub- or intra-loess till layer of the Dnieper (=Saalian) glaciation, which thus represents an important stratigraphic marker. The stratigraphy of these loesses is debatable due to different conceptions of the age of the Pryluki (pl) and Kaydaki (kd) palaeosols, separated by the Tyasmyn loess (ts), which lie over the Dnieper glaciogenic sediments and (sometimes) dn loess of the same period. Two schemes for correlating these units with marine isotope stages are currently in use: 1) till and/or loess dn are equivalent to MIS 8, palaeosol kd - MIS 7, loess ts - MIS 6, pedocomplex pl - MIS 5; 2) alternatively, unit dn (till, loess) are correlated with MIS 6, while units kd-ts-pl are combined with MIS 5. The post-recession loess-palaeosol sequences located on both sides of the Dnieper River (the Kremenchuk Reservoir) were selected for palaeogeographical and stratigraphic studies. These sequences are characterised by complex layering and variable lithology; palaeosols of the same age have different genetic profiles. A multidisciplinary study of these sites yielded lithological, geochemical, pedological, palaeontological, luminescence and AMS data. The results offer interesting reliable material for the reconstruction of the dynamics and directions of environmental changes as well as the evolution of loess landscapes after deglaciation of the Dnieper ice sheet in its marginal zone, the establishment of their enough precise chronological framework, and solid arguments for the stratigraphic distinctiveness of pl (S1; MIS 5) and kd (S2; MIS 7) palaeosols. They also contribute to a better understanding of the regional climatic context, as well as the link between similar sediments in continental scale.

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The coldest summer temperature in Serbian loess-palaeosol sequence Stari Slankamen during the MIS 12 – malacological evidence

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Stari Slankamen loess-palaeosol sequence (LPS) is located at the northern slope of Fruška gora mountain in the Carpathian basin, at the Tisza and Danube River confluence. It accumulated over nine glacial and interglacial cycles, thus being the oldest continuous terrestrial record of Pleistocene sediments in Serbia, and among the oldest studied LPSs in Europe. In this study, the malacological record of the Marine Isotope Stage (MIS) 12 is presented. The profile is sampled at 20 cm resolution for 4.8 m. The results from 15961 snail shells in total, from which 769 were too damaged to be identified, gave new insights into the glacial environment of the southern part of the Carpathian basin. Preliminary results show 27 mollusk species, more than half of which belong to mesophilous and highly tolerant species in terms of humidity and temperature, respectively. The MIS12 was shown to be more humid and cold compared to subsequent glacial cycles according to mollusks found in Serbian LPSs. Four results will be pointed out here:

- For the first time, the specie *Acanthinula aculeata* was found in Serbian loess.
- The *Orcula dolium* (today living in Alpine environment) was thriving, at some points making 20% population per the sample.
- The cold-resistant and frigophilous species comprised 14% of found snail population in entire MIS 12 which is not recorded in previous investigations of younger Serbian loess.
- July temperatures based on the malaco-thermometer method ranged from 14.4 °C to 19.7 °C.

The last result indicates that at some point the estimated July temperature was almost 8 °C lower compared to the modern. Still, the cold temperatures were not a restricting factor controlling the snail abundance, as there could be over 1500 shells per 10 kg of sediment. The warmer event indicated at the middle of loess unit L5 was also documented in equivalent chronostratigraphy at the Chinese loess plateau based on mollusk assemblage. The colder MIS 12 conditions over the Carpathian basin are in agreement with the pronounced glacier extent over its surrounding mountain systems and one of the strongest Pleistocene glacial environments in this part of Europe.

Unexpected light carbon isotope values from calcified root cells in a palaeosol (Chinese Loess): a result of contrasted seasons?

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Loess deposits are widespread in China and are important archives of Quaternary climate and environmental changes over East Asia. The alternance between palaeosols and loess units from the Chinese loess plateau (Central China) revealed that glacial and interglacial cycles are dominated by East Asian monsoon variations. Here, we study a loess profile in the northwest part of Beijing, the Fanshan loess profile, with a focus on the MIS 5 palaeosol and the loess units above and below. We investigate a potential new paleoenvironmental proxy: the calcified root cells (CRC) which are typical of herbaceous vegetation of steppe environments. These calcifications form relatively quickly (a few weeks to a few months) during the dry phases of the vegetation growing season. CRC concentration variability show a good correlation with the pedostratigraphy and grain size with high concentrations within the palaeosol and few CRC in the loess units. The high CRC concentration during the formation of the palaeosol suggest that the environment was favourable to the development of the vegetation. To better understand the past environment and climate, we measured the carbon isotope composition of the mineral phase and of the organic matter preserved in the CRC. Although the $\delta^{13}C$ of CRC for the organic matter do not shift from C_3 values, the $\delta^{13}C$ of CRC of calcite has an average of ~ -19‰, 5 unit below the expected values based on the root respiration. This signature is probably due to contrast seasonal period and might provide evidence for freeze-thaw processes during MIS 5 paleosol formation in the peri-desert zone. During the formation of this palaeosol, warm and humid conditions were prevailing and were associated with the development of the vegetation and the high abundance of the CRC. However, our isotopic signature suggest that winter season was characterized by cold and dry conditions (longer and intense) producing enriched soil ^{12}C reservoirs which was then pumped by the roots. By combining the carbon isotopic signature from the mineral phase and the organic matter, we have essential data on the carbon cycle in palaeosols.

(Mis)interpretation of grain size data of loess-paleosol sequences

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The proper interpretation of grain size data of aeolian dust deposits is of particular importance in environmental reconstructions. Today, modern methods for grain size determination and data processing are readily available to scientific researchers.

The uncertainties arising from the different chemical pretreatment of the samples and from the inadequate use of particle size determination methods are not addressed in this presentation.

Large number of research papers dealing with grain size data apply simple statistical descriptors and size-fraction ratios to draw conclusions on the stratigraphic, sedimentary and evolutionary meaning of granulometric data. This kind of approach which provide direct linkage among single statistical descriptors and wind speed, strength, distance from source area or aridity/extent of source areas is rather oversimplified as the grain size of sedimentary samples from aeolian dust deposits is influenced by an integrated effects of several concurrent processes and by several simultaneous environmental factors.

The simplified stratigraphic characteristics of the loess-paleosol sequence suggest that loess was formed from accumulated dust during the glacials, and the uppermost layers of loess were then pedogenised during the interglacials. The picture is also nuanced, to varying degrees in space and time, by glacial soil formation processes and interglacial dust accretion mechanisms. In this sense, the history of the development of an entire sedimentary series cannot be traced back to purely aeolian conditions.

Sedimentary subpopulations of (primarily) bimodal grain size distribution curves are decomposed by different mathematical methods (e.g., parametric curve fitting, end-member modeling). The loess sub-populations of parametric curve fitting are proposed to illustrate the background and the local-derived dust components for each sample. While the end-members of loess-paleosol samples can be regarded as representation of the average dust grain-size distribution of three temporal aeolian sediment clusters of seasonal or other short-term intervals.

Our aim is to discuss the main differences of frequently used statistical methods and to provide possible interpretations of the results by applying these various approaches on the high-resolution loess-paleosol record of Dunaszekcső, Hungary (Central Europe).

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Forward step for using silicon isotope ratio in paleoenvironmental studies: Si isotope fractionation in Norway spruce

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The importance of the plant-soil silica linkage is predicted by silicon making up a quarter of the mass of the earth's crust. The cycle of biogenic silica is faster than the dissolution of silica minerals from the earth's crust in the geochemical cycle. Thus, the composition of silicon isotopes in sedimentary diatoms, choanoflagellates, radiolarian tests, and sponge spicules seems to be a valuable indicator for dissolved silicic acid utilization and, therefore for paleoecological studies. Silicon isotope measurements in fossil remains of higher plants also provide a possibility to determine the rate of silicon usage. To understand the silicon isotope fractionation caused by the biochemical processes during the transport between silicon uptake and precipitation in a plant, silicon isotope fractionation in Picea abies [L.] H. Karst needles taken from different height-zones of a tree was measured by multi-collector inductively coupled plasma mass spectrometry (MC-ICP-MS). Our study demonstrates that we have to consider the intra-plant silicon fractionation, which was between -0.8 ‰ and 2.2 ‰ in spruce needles depending on the pathway length of the sap containing mono-silicic acid. The current study is the first report on silicon isotope fractionation in

Testing the potential of stable isotopic analysis of secondary carbonates from loess-palaeosol sequences in the southern Caucasus to understand hydroclimatic change and hominin population dynamics

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Stable isotopic (δ^{18}O and δ^{13}C) analysis of secondary carbonates forming in loess-palaeosol sequences have been demonstrated to provide a reliable record of long-term hydroclimatic changes in many regions across Eurasia. When combined with independent chronologies, these records allow for inferences to be made regarding the timing and nature of temperature and precipitation change during the Pleistocene.

The southern Caucasus contains many loess-palaeosol sequences, but these have seen relatively limited study in comparison to other loess regions in Eurasia. This is despite the fact that the region: 1) lies at an important intersection between the northern temperate, and southern subtropical climatic zones, and 2) has a rich Palaeolithic archaeological record containing evidence for multiple episodes of hominin expansion, cultural and technological change during the Pleistocene. Understanding long-term hydroclimatic change in the region is therefore of considerable importance.

Here, we report new results from the first systematic stable isotopic study of secondary carbonates in five loess-palaeosol sequences in the Armenian Highlands. We first present a description and independent absolute chronologies for each sedimentary succession. The morphology and petrology of the main carbonate facies (rhizoconcretions, nodular carbonates, laminar calcrete) identified are then explained, followed by the results of bulk stable isotope analysis of these facies. The δ^{18}O and δ^{13}C signatures of these carbonates are interpreted to provide inferences with regard to local environmental change and regional hydroclimatic variability. Through the integration of the stable isotope records and site chronologies, we demonstrate how the data improve our understanding of the spatial and temporal variation in hydroclimate regimes in the southern Caucasus, and the impacts on hominin population dynamics.

18O analyses of bulk lipids as novel paleoclimate tool in loess research – a pilot study

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The analysis of the stable oxygen isotopes ^{18}O and ^{16}O has revolutionized paleoclimate research since the middle of the last century. Particularly, δ^{18}O of ice cores from Greenland and Antarctica is used as a paleotemperature proxy and δ^{18}O of deep-sea sediments is used as a proxy for global ice volume. Important terrestrial archives to which δ^{18}O as a paleoclimate proxy is successfully applied are speleothems, lake sediments or tree rings. By contrast, δ^{18}O applications to loess-paleosol sequences (LPSs) are scarce. Here we present a first continuous δ^{18}O record (n=50) for the LPS Crvenka in Serbia, SE Europe, spanning the last glacial-interglacial cycle (~last 145 ka). From a methodological point of view, we took advantage of a recently proposed paleoclimate/-hydrological proxy based on bulk δ^{18}O analyses of plant-derived lipids. The Crvenka $\delta^{18}O_{\text{bulk lipid}}$ values range between -10.2 ‰ and +23.0 ‰ and are systematically more positive in the interglacial and interstadial (paleo-)soils corresponding to the marine oxygen-isotope stages (MIS) 1, 3 and 5, compared to the loess layers (MIS 2, 4 and 6). Our Crvenka $\delta^{18}O_{\text{bulk lipid}}$ record provides no evidence for the occurrence of interstadials and stadials comparable to the Dansgaard-Oeschger events known from the Greenland $\delta^{18}O_{\text{ice core}}$ records. Concerning the interpretation of our Crvenka $\delta^{18}O_{\text{bulk lipid}}$ record, plant-derived lipids such as fatty acids and alcohols are certainly strongly influenced by climatic factors such as temperature (via $\delta^{18}O_{\text{precipitation}}$) and relative air humidity (via ^{18}O enrichment of leaf water due to evapotranspiration). However, pool effects in the form of not water-correlated lipids such as sterols or input of root-derived lipids need to be considered, too. Similarly, the input of soil-microbial lipids and oxygen exchange reactions represent uncertainties challenging quantitative paleoclimate/-hydrologic reconstructions based on $\delta^{18}O_{\text{bulk lipid}}$ analyses from LPSs.

Pollen-based Holocene quantitative temperature reconstruction on the eastern Tibetan Plateau using a comprehensive method framework

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Quantitative climate reconstruction on long timescales can provide important insights for understanding the climate variability and providing valuable data for simulations. Unfortunately, the credibility of some attempts was hampered by incomplete reconstruction procedures. We here establish a comprehensive framework resting on high-quality Chinese modern pollen database, including modern pollen data screening, calibration set selection, major climate factor analysis, appropriate model selection, strict statistical assessment of results and ecological interpretation. The application of this framework to three high-resolution pollen records from the eastern Tibetan Plateau allows accurate quantitative inferences of Holocene temperature changes, which is the major control of regional vegetation. The results show that the mean warmest month temperature (MTwa) during the early Holocene was ca. 10.4°C and reached the highest value at 8.5–6 ka BP (ca. 11°C). The early and mid-Holocene (11–5 ka BP) warmth was followed by 1.2°C temperature decrease, culminating in the coolest temperatures of the Holocene during the Neoglacial cooling. Superimposing on the general cooling trend, MTwa reveals a significant 500-yr periodicity with varying intensities through time, showing that warm (cold) intervals are in phase with solar maxima (minima) periods. This spectral similarity indicates a possible connection of multi-century scale climate fluctuations with solar forcing.

Characterization and origin of the Clay-Rich Sediments from the Ases Cave (Mallorca, Spain)

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This work is the first study entirely focused on sedimentary deposits inside a cave in the Mallorca Island, specifically the sediments found in the Ases cave. A great number of coastal caves are located in Mallorca and are characterized by the magnificent presence of speleothems that have been studied for decades, especially those related to sea level variation. Nevertheless, the sedimentary deposits also present in these caves have not been studied in depth and that is the main objective of the work presented here. The analyses carried out on samples collected in the cave include the study of the grain size and the mineralogy of the deposits (X-rays and electron microscopy). Typically, the sediments are formed by calcite, quartz and clay minerals, with minor proportions of dolomite, albite, orthoclase, hematite, and goethite. The most important clay minerals are the illitic phases, kaolinite, smectite, and chlorite. The grain size and the electron microscopy studies have allowed to interpret the presence of different sedimentation processes: bedrock degradation, creep or saltation, and suspension; and different origins for the sediments: authigenic and detrital. Autochthonous deposits are located on the floor of chambers and corridors in subaqueous zones, indicating the stability over time of the mixing zone and, therefore, of the sea level. These deposits seem to be related principally to bedrock degradation. Allochthonous deposits are related to creep or saltation and suspension processes and appear filling voids on the walls and the ceiling in the terrestrial zone, evidencing the filling of the cavity in the presence of water (during a wet period). These results support the relevance of the study of these materials in paleoenvironmental studies in order to complete the understanding of the caves and their evolution.

Clarifying abrupt changes in the terrestrial environment on the Japanese archipelago from the aeolian sediments sequence between the end of the middle Pleistocene and the Holocene

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The Quaternary is a period of intense climate change characterized by glacial-interglacial cycles. During the process of warming in the cycles, abrupt cooling such as the Younger Dryas event and the Dansgaard-Oeschger cycle occurred. These cooling events have been triggered by changes in oceanic environment in the North Atlantic to the east of Greenland, and many related phenomena have been identified in Europe. On the other hand, considering how these changes affected East Asia is important for understanding global climate change. For example, Nilson and Lehmkuhl (2001) indicate that in the case of interpreting temporal patterns in the late Quaternary dust flux from Asia to the North Pacific, simplified assumptions concerning the reasons for dust variability may lead to incomplete or even erroneous palaeoecological conclusions. However, in order to analyze which Quaternary climate change events reported from Europe around the North Atlantic are linked to climate change events in East Asia, more specific field data are needed.

In this study, we perform continuous sampling of latest middle Pleistocene to Holocene volcanic loess soil distributed in the Japanese archipelago. Then, based on the analysis of various paleoenvironmental indices such as (1) characteristics of stratigraphy, (2) grain size distribution, (3) phytolith sequence, (4) ESR E_1' center signal change and (5) crystallinity of clay minerals and plagioclase, we try to reveal abrupt terrestrial environment changes with a time scale of several hundred years order. In future, we will apply similar analyses to loess samples in the western part of the Eurasian continent. Finally, by comparing such analyses, we would like to discuss on the global and the local - regional changes related to the terrestrial environment during the period.

Harder, Better, Faster, Stronger - new insights on the frequency and hazard risks of extremely large volcanic eruptions (VEI≥7) from polar ice cores

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Large-magnitude volcanic eruptions, are considered the most severe natural global catastrophic risk, because they are able to eject large amounts of fine particles (e.g. sulfuric aerosols) into the stratosphere, where block incoming solar radiation. Our ability to predict the global hazards and risks to society of future volcanic sulfur injections is, however, compromised by the lack of a complete record of global volcanism with well-constrained evidence of timing and magnitudes of stratospheric sulfur aerosol injections. In order to mitigate and adapt to the climate effects of future large volcanic eruptions we need to better quantify the risk of these eruptions including (a) the probability of their occurrence and (b) their expected climatic impact.
Well-dated, high-time-resolution ice-core measurements provide, if not the only, certainly the most direct and detailed records of atmospheric aerosol concentrations before recent decades when instrumental and satellite measurements began. Sulfate and ash preserved in ice layers allow us to reconstruct the timing and associated stratospheric sulfate content of past volcanic events.
Here we use arrays of synchronized, accurately dated, high-resolution ice-core aerosol records from Greenland and Antarctica to reconstruct the timing, sulfur injections and likely source locations or latitudes of > 2000 volcanic eruptions occurring during the last Glacial (60-11.7 ka BP) and Holocene (the past 11,500 years) to answer the questions:
1) What is the likelihood of a stratospheric sulfur injection comparable in strength to that of Tambora in 1815 CE or of Toba in 74 ka BP to occur somewhere on the globe within the next 100 years?
2) How has subaerial volcanic activity changed in space and time throughout the last Glacial and Holocene?
We further demonstrate how state-of-the-art continuous-flow-analyses of ice cores combined with geochemical fingerprinting techniques performed on minute amounts of volcanic acids and cryptotephra shards present in polar ice can be used to detect and identify the source of past volcanic eruptions (including "supereruptions") sometimes even when these occurred more than 10,000 km away from the ice-sheets.

Signature of volcanic climatic impacts recorded in the Astronomical Diaries and Related Texts from Babylonia

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The *Astronomical Diaries and Related Texts from Babylonia* represents a compilation of the oldest continuous written weather records in the ancient world. These diaries date from 652-61 BCE with a majority of the surviving data spanning from ~390-61 BCE. Following a process of coding and cataloguing these data into an analysable dataset, the researcher is currently reconstructing the climate for the region in this period, with some exciting results unfolding. During the timeframe represented by the diaries, there are approximately 30 notable explosive volcanic eruptions captured by polar ice-core sulphate deposition data. Some of these eruptions are likely to have impacted on Babylonian climate, and potentially also society, with evidence preserved within the *Astronomical Diaries*. The extent to which the *Diaries* will capture the impact of all such eruptions is however tempered by factors such the distribution of missing diaries and other biases through time. For example, the climatic impact of the major tropical eruption of 168 BCE is not captured in the diaries because of missing data. This paper will highlight the signature of volcanic climatic impacts as evident in the recorded observations. Signatures uncovered thus far include increased impacts on the levels of the Euphrates river, recording of severe cold, alongside terms such as “the disk of the sun looked like that of the moon”, and the “sun set (or rose) in a box (or black cloud)”. These will be discussed in parallel with the scale of omissions, an intriguing aspect of the *Diaries*.

Volcanic Eruptions and Civil War in Persia - 424 and 465 BCE

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In 465 BCE a coup against Xerxes I brought to an end his reign as ruler of the Persian empire. Records from the Persepolis Tablets show that there is a very distinct spike - a unique moment in the reign of Xerxes I - when silver was disbursed by the administration instead of grain. In the year 424 BCE civil war broke out in the Near East in the aftermath of the death of the Persian emperor Artaxerxes. The only legitimate son, Xerxes II, became ruler. He held power for just forty-five days, before a coup took place, plunging the empire into a crisis. Evidence from Murašû Archive indicates that it was also a year of exceptional economic crisis, when landowners failed to pay taxes in crops and sought to mortgage their land for silver. In both cases the outbreak of civil war co-incided with the aftermath of a major volcanic eruption, strongly suggesting that these events were triggered by the impact of the volcanoes on agriculture.

Tracing the Social and Environmental Dimensions of Volcanic-induced Climate Change in the 1st Millennium AD

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Volcanic eruptions are one of the natural disasters that have raised short-lived climate change, which has potentially affected the human-environment relationship in prehistoric and historic times. Many paleoclimatic records are consistent that the first half of the 1st millennium AD is a tumultuous time of environmental, societal, agricultural, and political turbulence. At least three large volcanic eruptions occurred during that period in AD 536, AD 540, and AD 547. Whether or not these volcanic eruptions triggered the Late Antique Little Ice Age and had profound effects on social disruption from AD536-660 in the Northern Hemisphere is a matter of debate. Lake sediments record paleoclimatic and paleoenvironmental dynamics as climate variability, vegetation, settlement history, and trace effects of volcanic eruptions. In this study, an annually laminated sequence from Lake Kleiner Tornowsee, Northeastern Germany, was selected and a multiproxy approach including palynology, tephra analysis, XRF-geochemistry, varve, 14C-AMS dating, and age-depth modeling was conducted for the time window AD 330-1320 to disentangle the potential effects of the volcanic eruptions on climate variability and societal and environmental changes. Our data depict that the 1st millennium AD was a time of climatic, demographic, and environmental changes in North-eastern Germany. The volcanic eruption (tephra in 381cm; AD 364) was followed by a decline of anthropogenic indicators (API) (e.g. *Secale*, and Cereal-type) reflecting the start of the so-called "migration period" in the region. A woodland re-expansion is visible in the time window AD430-580. A high level of environmental impact was experienced during the Slavonic occupation from AD580 to AD 770 and in AD1170-1330 where there is a high value of Anthropogenic indicators (API) is the onset of Germanic colonization.

Keywords: Pollen, Tephra, Annually Laminated Lake Sediment, Climate, Migration

A proxy-based semi-stochastic ensemble reconstruction of volcanic climate forcing for the last glacial cycle (130,000 – 50 BP)

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Perturbations in stratospheric aerosol due to explosive volcanic eruptions are a primary contributor to natural climate variability. Observations of stratospheric aerosol are available for the past decades, and information from ice cores has been used to derive estimates of stratospheric sulfur injections and aerosol optical depth over the Holocene (10,000 BP to present) and into the last glacial period, extending back to 60,000 BP. Tephra records of past volcanism, compared to ice cores, are less complete, but extend much further into the past. To support model studies of the potential impacts of explosive volcanism on climate variability over glacial timescales, we present here an ensemble reconstruction of volcanic stratospheric sulfur injection (VSSI) over the last 130,000 years that is based primarily on terrestrial and marine tephra records. VSSI values are computed as a simple function of eruption magnitude, based on VSSI estimates from ice cores and satellite observations for identified eruptions. To correct for the incompleteness of the tephra record, we include stochastically generated synthetic eruptions, assuming a constant background eruption frequency from the ice core Holocene record. While the reconstruction often differs from ice core estimates for specific eruptions due to uncertainties in the reconstruction method, it shows good agreement with an ice core based VSSI reconstruction in terms of millennial-scale cumulative VSSI variations over the Holocene.

Monitoring and hazard assessment of Kolumbo submarine volcano, Greece

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The Santorini volcano in the South Aegean Sea (Greece) is one of the most important and famous volcanoes in the world, with numerous large-volume explosive eruptions and caldera-forming events over the last 600.000 years. It is widely famous for its 3600BP Minoan eruption which had a catastrophic impact on the Minoan civilization in the island of Crete in Eastern Mediterranean Sea. The Santorini volcano, however, is but one volcano in a tectonically controlled domain that trends SW-NE in the Southern Aegean Sea. Other volcanoes are submarine and only partially explored.

Off the north coast of Santorini lies the Kolumbo volcanic chain, which consists of 25 submarine cores and craters and extends NE along the floor of the Anhydros Basin. The largest of those is the Kolumbo crater, one of the most active Mediterranean submarine volcanoes. Kolumbo erupted explosively in 1650 AD and caused significant damage and 70 fatalities on Santorini Island. In 2006, the R/V Endeavor made a significant discovery of an active, pumice-hosted, diffuse-flow, high-temperature (> 260°C) hydrothermal vent field in Kolumbo's crater at 500 m depth, which hosts the only known, actively- forming, Au-Ag-Tl-Sb-Hg-As(± Bi,Te, Mo)-rich, CO_2-venting seafloor massive sulfide chimneys and mounds related to continental margin volcanism. Owing to its vicinity to highly populated areas such as Santorini, the submarine volcano and its hydrothermal vent field pose significant risks in the form of geohazards such as earthquakes, tsunami, and toxic metal(loid)s and gasses while our knowledge remains severely limited on the repercussions of this type of volcanic activity. To address such risks, long-term, continuous, and high-resolution monitoring is required.

The SANTORY (SANTORini's seafloor volcanic observatorY) Research Program aims to monitor the Kolumbo system and how the regional tectonics affect or control its activity. Additionally, by using state-of-the-art equipment, SANTORY investigates how the volcano, and its physicochemical hydrothermal processes impact the surrounding environment and the threats that imposes to the nearby communities that yearly attract thousands of tourists. To understand how the Kolumbo hydrothermal system affects not only the seafloor morphology, but also the citizens of the nearby islands, in situ observations of these structures are highly important.

Improved source attribution of 7th Century CE volcanism from evidence in Greenland ice

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Polar ice core records reveal several volcanic events during the 7th Century of the Common Era (CE), preserved as large peaks in deposited sulfate aerosol. In particular, eruptions during 626 and 682 CE are among the 25 largest events of the last 2500 years recorded in ice. Negative tree-growth anomalies and historical records indicate these eruptions were climatically significant, due to cooling associated with sulfate aerosol injection to the stratosphere.

Previous studies using ice core evidence have assumed either a tropical or mid-high latitude source for these eruptions based on the deposition of volcanic aerosol in one or both Greenland and Antarctic ice cores. However, the possibility of simultaneous high latitude eruptions in each hemisphere makes this assumption problematic, potentially leading to incorrect sulfur injection and climate forcing estimations.

High-resolution sulfur isotope analysis of aerosol deposited in polar ice provides a method informing us if a volcanic plume reached above the ozone layer by the presence of a mass independent fractionation signature, while differences in tropical and extra-tropical isotopic signals indicates source latitude.

We apply this technique to eruptions recorded in Greenland ice core Tunu2013 to test previous tropical or mid-high latitude source attributions of 4 eruptions during the 7th Century: 626, 682, 686 and 698 CE. Measured isotopic signatures allow us to better interpret eruptive source latitude for each event, aiding calculation of stratospheric sulfate contribution and therefore climate forcing associated with volcanism during this time period. In addition, we use major oxide geochemical fingerprinting of cryptotephra associated with the aerosol deposits in polar ice to give further insights to the sources of 7th Century eruptions

Simulated climate variability at the end of the mid-Holocene

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The Holocene epoch witnessed some extreme climatic events. The 4.2 ka BP event is one of the most severe climatic events that caused cooling and droughts in some parts of the world. Archaeological evidences show that many ancient civilizations collapsed during this period and it was also a period of large human migrations. The 4.2 ka BP event is still not well understood with regard to its triggering mechanism, however, reconstructions show weaker and narrower monsoons, consistently with mutidecadal-to-centennial mega-drought regimes. Here, we have analysed the migration of Asian monsoon fringe in a new set climate model simulations of the last 8000 years with the Max Planck Institute Earth System Model (MPI-ESM1.2). We have used the standard "slow forcing" simulation, that includes temporal evolution of CO2 and orbital forcing, and the "full forcing" simulation that includes additionally clusters of volcanic eruptions throughout the Holocene. We have found signal of decreased precipitation in the Indus valley, although the influence of the internal climate variability is so large preventing to attribute the 4.2 ka BP Asian mega-drought to volcanic forcing.

Leaf wax dD and pollen from a lake in Southeastern Norway reflect Iron and Viking Age climate variability

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In Northwestern Europe, the first millennium CE was characterized by climatic anomalies and cultural shifts, with the mid-6th century being one of the coldest periods in the past 2000 years, initiated by volcanic eruptions in 536 CE and 540 CE. In Norway, lack of archaeological finds from the mid-6th century has long been linked to societal crisis, crop failure and famine. However, the extent and timing of both the volcanic induced cooling and societal changes remains disputed, partly due to the lack of high-resolution reconstructions from natural archives.

Here, we reconstruct precipitation and lake water isotope variability from the analysis of leaf wax hydrogen isotopes (dD values) through the first millennium CE from Lake Sagtjernet in Southeastern Norway. We further analyse sedimentary pollen to give insight to the environmental changes of the region during this period. Samples from the varved sediments are analyzed at a high resolution (10-year frequency) during the period 400-800 Common Era (CE).

In the period 400-800 CE, we find significant changes in the variability of dD values that we interpret as changes in precipitation. These data show an increase in moisture delivery starting at c. 500 CE, followed by a rapid decrease in c. 550 CE (15 ‰ drop across 25 years). The corresponding pollen data show a decrease in cultivated species and increase in trees during the same period, indicating a decrease in human activities in the area. Finally, we review the precision and accuracy of the age model and its effects on the interpretation of the data and discuss our results in light of the archeology of the region.

No evidence of winter warming within Eurasia following large, low latitude eruptions over the Last Millennium

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We critically reexamine the question of whether volcanic eruptions cause surface warming over Eurasia in wintertime, in the light of recent modeling studies which have suggested that internal variability may overwhelm any forced volcanic response, even for the very largest eruptions during the Common Era. Focusing on the Common Era, we combine model output, instrumental observations, tree-ring records, and ice cores, and build a new temperature reconstruction that specifically targets the boreal winter season. Using the latest volcanic forcing reconstruction, we identify 20 eruptions over the Last Millennium withvolcanic stratospheric sulfur injections (VSSI) larger than the 1991 Pinatubo eruption.

We find that 13 of these 20 events are followed by cold surface temperature anomalies over Eurasia in the first post-eruption winter, as one might expect from volcanic aerosolsimpacts on surface solar radiation. We find no evidence that the North Atlantic Oscillation is correlated with VSSI in winter. We also find, however, that internal variability is very large: the greatest post-eruption winter cooling occurs in the winter of 1600-1601, following the Huaynaputina eruption, which is only the 7th largest eruption in terms of VSSI.

Furthermore, by carefully examining individual events, and comparing our new reconstruction with additional reconstructions, we are able to reconcile our findings with those of previous studies. Beyond the uncertainties in the reconstruction and volcanic dating, we demonstrate that earlier claims of post-eruption winter warming primarily originated from averaging small eruptions with larger ones, thus diluting with noise the small cooling signal from the volcanic aerosols.

Elemental contents in a 200-yr marine sediment core from Santa Barbara Basin measured by scanning XRF, acid-leach and aqua regia dissolution ICPOES approaches: Analytic method matters (e.g., Pb pollution)

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Elemental contents in SBB-8-2012 core measured by an iTRAX core scanner (scanning XRF), 0.5N HCl acid leach (AL) and aqua regia (AR) have been discussed. The variation patterns of Ca and Sr contents on long-term scales are similar in three approaches as well as in AL and AR concentrations because the two elements come mainly from authigenic phases. AL/AR Fe (%) is averaged 25.7±8.7%, and the ratio is strongly correlated with AL Fe concentration (R^2 = 0.92), indicating that although the authigenic Fe is only 25% of the total Fe, it dominates the Fe variation especially when marine productivity increases. The scanning XRF Fe variation does not follow the variation pattern of acid dissolved Fe concentrations, unless the authigenic Fe becomes dominant. AL/AR Ti (%) is averaged 4.8±1.3%, and the ratio is positively correlated with AL Ti (R^2 = 0.63) but negatively correlated with AR Ti (R^2 = 0.62), indicating both authigenic (AL) Ti and detrital (mainly AR) Ti influence the variation pattern of Ti. The scanning XRF Ti variation does not agree with neither AL Ti nor AR Ti variation patterns. However, the scanning XRF Ti may represent the relative variation of total Ti in all phases on the core surface sediments. The average AL/AR Pb is 65.7±14.8%, reflecting the authigenic Pb is majority. The AL and AR Pb average concentrations were 5.6±0.9 and 9.8±2.1, 8.0±0.6 and 9.4±1.3, 8.5±0.8 and 17.4±4.1, 12.5±1.5 and 16.6±2.3, and 10.3±1.4 and 16.8±4.5 during the periods of 1820-1880, 1880-1895, 1895-1907, 1908-1978 and 1979-2012, respectively. Before 1880, the Pb was the lowest and stable. Slightly increased in AL Pb from 1880 to 1895, showing human influence began. Sharp increase in AR Pb but not in AL Pb during 1895-1907 might be due to mining activity near the Basin. From 1910 to 1978, the AL Pb was the highest and reached the maximum at 1978, reflecting atmospheric input from leaded gasoline consumption. After the ban of leaded gasoline usage in 1976, the AL Pb dropped quickly. The scanning XRF Pb does not agree with both AL Pb and AR Pb patterns.

Investigating seawater-shell relationships using tank experiments with living Tridacna to inform palaeoenvironmental reconstructions

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High-resolution past climate reconstructions of marine shells provide crucial baselines for understanding global environmental changes, allowing better adaptations to current and future climate changes. Giant clam shells (*Tridacnidae spp.*) are novel and reliable paleoenvironmental archives with many available geochemical proxies from which paleoclimate records can be faithfully reconstructed. For example, sea-surface temperature (SST), sea-surface salinity (SSS), dissolved inorganic carbon (DIC), insolation, rainfall, river input, marine primary productivity and extreme weather events can be detected at ultra-high resolution using both stable isotopes and trace elements. However, the specific relationship between paleoenvironmental parameters and giant clam shell geochemical composition is still not clear. Most previous research has used instrumental records to compare the accuracy of giant clam paleoenvironment reconstructions, which can often only provide qualitative reconstructions as their geochemical signals may be affected by multiple environmental variables.

In this ongoing research, a tank experiment is being used to culture giant clams whilst varying environmental parameters, including SST, SSS, insolation and primary productivity. In this lab setting, we can minimize the complexities that arise in the natural environment and control for single environmental variables. We have defined 28 culture conditions to maximize replication and to avoid cross-impacting of variables. The clams will live in each set of conditions for two weeks to grow an estimated ~0.7 mm increments for further geochemical analysis.

This study will: (1) decipher the relationship between *Tridacna* shell calcification rates and environmental variations; (2) investigate the relationship between seawater parameters (SST, SSS, insolation and primary productivities) and giant clam shell geochemical compositions (Sr/Ca, Mg/Ca, Ba/Ca, Fe/Ca, $\delta^{13}C$, $\delta^{18}O$); and (3) build predictive equations to quantitatively reconstruct high-resolution paleoenvironmental conditions from *Tridacna* geochemistry.

A fast, non-destructive and low-cost dating approach of sediment cores over the last century

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Sediments from lakes and peat bogs are good archives to study changes that have occurred in the Earth system over the last century and older. However, developing such studies requires accurately dating the sediment accumulations. The common techniques are short-lived radionuclides (^{210}Pb, ^{137}Cs, and ^{241}Am) for recent sediments and radiocarbon analyses for older sediments. However, these methods are relatively expensive and not fast to acquired. Consequently, they are not adapted when the aim is to work on a large set of sediment cores. This is particularly the case when the research objectives are to look at the representativity of a proxy based on a modern reference dataset. In palaeosciences, such modern references are frequently used for calibrations. These studies are often based on a collection of surface samples with the same thickness that may not cover the same time period depending on the sites due to various sedimentation rates. These temporal differences may lead to biases in the calibration studies.

Here, we propose a fast, non-destructive and relatively cheap approach to provide a chronology that can be used to develop a referential or to help the sampling strategy and/or to improve/validate age-depth models based on classical analyses.

Our protocol is based on known lead pollutions providing chronological markers for the last century and the Medieval and Roman periods. These lead pollutions can be observed by X-ray fluorescence core scanner analysis. Three markers can be identified for the last century: the lead peak before the oil crisis in 1973, the postWorld War 2 (1950) and end of Second Industrial Revolution in 1910 increases. Two older and less precisely dated peaks can be recorded, which correspond to the extraction and processing of ores during the Middle Ages and Roman period.

In this poster, we present our approach applied to 23 lakes and 14 peat bogs; it has been independently validated on 6 different sites by short-lived radionuclides and radiocarbon dates. Although this approach was successfully applied in most cases, the results should be taken with caution and combined with the other established methods or chronological markers from historical events (earthquakes, floods, avalanches…).

The role of large-scale climate oscillations on the annual deposition of varve couplets in Crawford Lake, Ontario, Canada

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Due to its approximately 500-year record of undisturbed annually deposited varve couplets, Crawford Lake, Ontario, Canada is under consideration for the Global Boundary Stratotype Section and Point (GSSP) of the Anthropocene. This new epoch is characterized by the influence of industrialization on the geologic record. Annual varve couplets are divisible into seasonal pairs: light-coloured, calcite-rich laminae deposited in the summer and dark-coloured, organic-rich laminae deposited in the winter.
The thicknesses of these laminae are influenced by environmental and climatic conditions at the site. Varve deposition during the industrial era, specifically between 1870 and 2000, is examined to assess the influence of large-scale natural climate oscillations on the Crawford Lake system during a time of anthropogenic influence. Using cross wavelet transforms (XWTs), the records of seasonal laminae are compared to a variety of climate oscillations to establish any relationships between the two cyclical events. The 11-year Schwabe Solar Cycle (SSC) and the Pacific Decadal Oscillation (PDO) are correlated particularly strongly with the quasi-decadal and interdecadal oscillations in laminae thickness, respectively. Furthermore, interactions between the SSC and PDO influence the phase of the relationship between the SSC and the light laminae. The El Nino Southern Oscillation (ENSO) and the Arctic Oscillation (AO) are also correlated, albeit less strongly, with some interannual to quasi-decadal oscillatory behaviour in the laminae records.

Using millimetre scale pollen analysis to resolve distal vegetation responses to the 25.5 ka Ōruanui supereruption, New Zealand

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The ~25.5 ka Ōruanui supereruption from Taupō volcano, New Zealand, is the youngest known supereruption globally, erupting >1,100 km^3 of pyroclastic material during the Last Glacial Maximum. Impacts of this event on climate and the New Zealand environment remain unresolved, particularly on ecological timescales, due to incomplete or low-resolution geological records. Using sediment cores from Onepoto maar palaeolake, Auckland (~240 km upwind from source), pollen assemblages were analysed at contiguous 1-mm intervals, directly above and below the intact 3-cm-thick Kawakawa-Ōruanui Tephra layer to assess post-eruptive vegetation responses. At the time of the eruption, the Auckland region was cooler, drier, and windier with a terrestrial landscape occupied by established closed canopy beech forest. Sediments immediately above the tephra record a decline in the relative abundance of pollen from the dominant canopy species of *Fuscospora*, and concurrent increase in the relative abundance of grasses, herbs, ferns, and shrubs. These changes reflect a temporary (<10 years), part-defoliation of trees in the forest canopy, which likely would have permitted more light to penetrate and to encourage sub-canopy vegetation growth. In addition, increased relative abundances of pollen from wetland/aquatic taxa lasted for ~60 years and are consistent with increased light availability, terrigenous sedimentation and nutrient flux in the catchment prompting a temporary expansion of wetland and littoral margins. Overall, the palynological record principally reflects the immediate and direct impact of ashfall on vegetation following the eruption. A short-lived volcanogenic cooling can be inferred from Antarctic ice core records and may have had a possible compounding, albeit minor effect at Onepoto, but this cannot be distinguished from the ecological impacts. These insights into rapid and enduring vegetation responses and landscape recovery to a supereruption are only possible due to the fine sampling resolution used. Our results demonstrate the value of millimetre-scale stratigraphic pollen analysis from non-varved lacustrine sediments as a tool for assessing ecological responses to past disturbance events, particularly explosive volcanic eruptions, on sub-decadal timescales.

Extracting seasonal climate signals from land-use events with updated Lake Nautajärvi (Finland) clastic-biogenic varve section

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Annually laminated (varved) lake sediments can provide high-resolution information on past environmental, climatic and human-induced changes. However, the comparison to short instrumental weather and hydrological records requires exceptional chronological accuracy in subannual level as well as detailed study on land-use history and understanding of the unique catchment area and lake basin dynamics. The well-studied Lake Nautajärvi is a small dimictic lake in southern central Finland with circa 10 000-year long clastic-biogenic varve record. Seasonal sedimentation processes and the formation of Lake Nautajärvi clastic-biogenic varves have been previously confirmed with monitored sediment trap study.

In this study, freeze cores taken in years 1999, 2011, 2021 enabled us to observe the recent varve formation and preservation processes, sediment compaction rate and connect the existing varve chronology from 1999 to present-day. In addition, the existing varve chronology was verified with high-resolution 137Cs dating and land-use marker horizons. In this study, we were able to collect high-resolution annual and seasonal subsamples to reconstruct the 1986-year 137Cs Chernobyl marker horizon on a seasonal level (spring-summer 1986).

Epoxy embedded samples from fresh cores taken in 1999, 2011 and 2021 were used to reveal recent short-term geochemical (ITRAX) and physical changes (grain size, computed tomography density) in seasonal and annual level. In addition, human-induced changes in catchment area were recorded from maps, aerial photographs and other archives. This study focused on connecting the extreme weather or hydrological events in the region with changes in geochemical and physical proxies. With updated chronology and land-use history study we were able to extract extreme land-use event related varves and to distinguish the changes in autumn and winter precipitation and discharge events, especially prolonged dry periods, in biogenic lamina properties.

Replicability of high-resolution sea surface temperature records in proximal Santa Barbara Basin sediment cores

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Determining the magnitude of natural climate variability is necessary for predicting the plausible range of future climates and to test climate models. As the instrumental record is too short, the analysis of proxy records can provide crucial information about climate variability from sub-annual to centennial timescales or longer and across critical climate transitions. However, current marine paleoclimate records are often too coarse in temporal resolution, noisy and show low reproducibility - either pointing to low information content or to more pronounced local climate variability than predicted by climate models.
The sediments of the Santa Barbara Basin (SBB), California, offer an ideal setting to quantify the robustness and representativity of marine proxy records and to reconstruct past climate variability. Suboxic bottom waters and strong seasonal sedimentation create a varved record that has been well-studied and has precise age control over the last millennia. Mass spectrometry imaging (MSI) using laser-based desorption/ionization allows sub-mm scale mapping of molecular proxies and the creation of proxy records with up to monthly resolution. In particular, targeting alkenones of haptophyte algae and the derived proxy has been shown to accurately capture the interannual variations in sea surface temperature in modern samples from the anoxic center of SBB.
In this study, we compare two previous MSI records and records from four additional cores along a bathymetric and oxygenation gradient (~14 km) in terms of elemental composition (X-Ray Fluorescence) and MSI-based $U^{K'}_{37}$ records. This allows us to estimate the magnitude of local noise and the shared climatic signal. We further investigate how well the shared regional signal captures the sub-annual to decadal variability of the Californian current system as known from the local instrumental record.

Our results shed light on the spatial representativeness of sedimentary archives and on the robustness of the environmental proxy record. They further provide the basis to develop optimal sampling and measurement strategies to reconstruct the past temperature evolution with explicit uncertainty estimates. Such replicated ultra-high temporal resolution archives are needed to close our knowledge gaps on the societally relevant decadal to centennial natural climate variability.

Antarctic sea ice in a changing planet – insights from palaeoclimate archives.

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Sea ice is currently undergoing major changes. Observations of both Antarctic and Arctic sea ice conditions are limited to the satellite era (post 1970). Prior to the satellite era (post-1970) and historical records (post-1930s), the best method for reconstructing past sea ice conditions comes from palaeoclimate archives. Changes in Antarctic sea ice conditions have been reconstructed from the chemical or isotopic records measured in continental ice cores and from microfossil or geochemical tracers in marine sediment cores. Marine records typically assess changes in sea ice over millennial timescales, with only a few produced at sub-decadal resolution. Conversely, ice core records are available at annual resolution or higher but the longest coastal ice core records extend just a few hundred years, which is arguably too short a time period to investigate the full range of natural variability (Thomas et al., 2019). Amalgamating these archives offers the best potential to enhance our understanding of longer term variability and place the recent changes in an extended context.

Many of the existing marine cores with sea ice records have sufficiently high sedimentation rates (≥50 cm/ka) to permit higher resolution reconstructions. By increasing the resolution of marine records, particularly in areas where ice cores exist, we can combine the marine and ice core records to provide a continuous record of sea ice that overlaps with satellite and historical data at the highest resolution and extends back over the last millennia to resolve natural variability.

This project aims to enhance Antarctic sea ice records by combining existing marine and ice core archives. This will include targeting key areas where records can be considered in parallel, adapting the sampling scheme, increasing the resolution of existing marine records and analysing newly discovered chemical proxies in the ice, to improve alignment between the ice core and marine sediment records.

High-resolution paleomagnetic dating of a long maar lake sediment sequence from the Leizhou Peninsula, South China

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Understanding longer-term dynamics of the East Asian monsoon is important and has implications for the evolution of environments in Asia during the Quaternary. Continuous, reliable monsoon climate records from lake sediments of terrestrial South China that encompass several glacial-interglacial cycles are, however, lacking. Here, we apply palaeomagnetic methods to two newly drilled long (>220 m) parallel cores (TY1 and TY2) from the Tianyang (TY) maar lake, South China, which lies within the East Asian monsoon core region, to reconstruct variations in monsoon precipitation over an extended period of the upper Quaternary. The results of alternating field (A.F.) demagnetization show that the entire sediment sequence was deposited in the Brunhes normal chron, including eight possible magnetic alternations. Using anhysteretic remanent magnetization (ARM) to normalize natural remanent magnetization (NRM), we calculated the relative paleointensity (RPI) of the past magnetic field from the TY2 core sediments. The RPI record is consistent with global reference RPI stacks (Sint-800 and PISO-1500) and this enables us to obtain 17 age fitting points. Using these fitting points, a chronological framework for the TY maar lake sediment sequence is constructed and referenced against a published independently obtained chronology of the upper part (~38 m) of the core. The basal age of sediments is thus calculated 707.3 ka, indicating a mean sedimentation rate of 31.4 cm/kyr. Our continuous, high-resolution (2 cm interval) measurements of magnetic susceptibility yield a time series exhibiting pronounced lows and highs. Magnetic susceptibility of the sediments reflects monsoon precipitation variations, whereby high values indicate greater precipitation and low values less precipitation. The TY maar lake sediments reveal dominant precessional and semi-precessional cycles, evidencing low-latitude insolation forcing on tropical monsoon precipitation variations over the past 700,000 years. The record provides the first robust and independent chronology for a maar lake sediment sequence in the subtropical monsoon region of East Asia, and reveals variations in monsoon precipitation over the past seven glacial-interglacial cycles.

Keywords: Paleomagnetism; geomagnetic paleointensity; maar lake; glacial-interglacial cycles; East Asian monsoon

Considerations on the application of magnetic properties to estimate the provenance of marine sediments: use of a new methodology in a case study in the early Quaternary

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The provenance of marine sediments is usually defined through geochemical proxies. In general, these techniques are destructive, which require a large amount of sample, time, and have a high financial cost.
Magnetic parameters can be used to determine provenance through the ratio of physical to magnetic grain size (Mrs/Ms ratio) in different grain size fractions, using non-destructive, fast methods with require a small amount of sample.
Unusual magnetic techniques were used to determine the provenance of sediments during glacial and interglacial periods in the early Pleistocene in North Atlantic, with excellent results when compared to the geochemical data. The results showed that most of the particles came from Icelandic basalts with the magnetic grain size smaller and incompatible to the physical grain size, while in glacial cycles the amount of non-basaltic material increases, with the physical grain size comparable to the magnetic grain size.
Less than 0.2 g of sediment was used for each fraction, not exceeding 1.2 g of sediment to analyze 6 different grain size fractions. Good results depend on the difference between the magnetic grain size of the possible source areas as well as the separation of the grain size fractions. It was observed that there is no need for the separation of very coarse silt, coarse silt, and medium silt as they show very similar results. In this way we decrease the required analysis and preparation time. The separation of the fine and very fine silt is necessary to remedy the magnetic grain size overlap of the clay fraction, as these fractions have similar hydrodynamic behavior. Separation of the sand from the rest of the sample is vital, as it can provide opposite signals to the other fractions, with a higher IRD contribution. FORC diagrams of the sediment were made but did not show very enlightening results, exhibiting very less change in magnetic signals.
This study concluded that the application of magnetic properties to define the provenance of marine sediments has certain restrictions, but presents very promising results, with some modifications to optimize the time of analysis and decrease the amount of material used.

Refining the chronological framework of MIS 5c-d millennial climate variability using 40Ar/39Ar and proximal-distal correlations of Mediterranean tephra units erupted from Campi Flegrei, southern Italy

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Precisely determining timing and chronology of millennial-scale climate variability is fundamental for understanding past climate dynamics. Paleoclimate studies frequently rely on chronologies underpinned by orbital tuning, which can lead to erroneous reconstructions. Absolute chronology based on radiometric dating allows instead assessing the timing of the climate variability independently of any uncertainty and a priori assumption inherent in orbital tuning process. In this framework, tephra layers preserved in sedimentary sequences and hosting K-rich minerals (e.g., sanidine, leucite) can be dated by means of single crystal $^{40}Ar/^{39}Ar$ laser fusion technique, providing the needed chronological constraints. Furthermore, these same tephra layers can be correlated over great distances to synchronize past climate events at regional scale. Tephra layers of supposedly Campanian origin (i.e., X-6, X-5, C-22) preserved in Mediterranean Marine Isotope Stage (MIS) 5 sedimentary records have long been used as tie points for correlation purposes. They have also been documented in numerous paleolithic successions of the Mediterranean and Europe areas, providing fundamental stratigraphic and chronological constrains for archaeological investigations in these regions. However, the specific volcanic source(s) of these tephra layers has never been determined and uncertainties still exist on their spatial distributions and ages. Here we present new geochemical (major, minor and trace elements, Sr-Nd isotope ratios) and geochronological ($^{40}Ar/^{39}Ar$ ages) data of 5 ash-fall units from the Campanian Plain. Our data allowed the identification of the medial equivalents of the MIS 5 tephra markers, including the widespread C-22, X-5, and X-6 tephra, and their assignment to a previously undocumented Campi Flegrei activity in the time span between 109 ka and 92 ka. In addition to substantially extending the Campi Flegrei explosive activity back in time, and thus providing the basis for a revaluation of its explosive history, our findings provide new precise radiometric dating to better constrain the chronology of the millennial scale climatic oscillations of the MIS 5c-d in the Mediterranean area and possibly on a larger scale. Finally, results from this study allowed a review of previous correlations proposed for these MIS 5 Campi Flegrei tephra in the central Mediterranean area.

The upper boundary of the Eemian Interglacial in Central Europe compared to the marine and ice cores

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The Eemian Interglacial, detailed described in Central Europe, including Poland, on the basis of palynological data from many fossil lakes and bogs, is commonly correlated with the MIS-5e. Also the correlation of the Brørup *sensu lato*, the oldest European interstadial of the Last Glaciation, with MIS-5c is beyond any doubt. It is tripartite in Europe. Cooling in its middle part is correlated with the marine C-23 event and Greenland GS-24 stadial. It separates two warmer periods – the older one corresponds to the marine W-23 warming and ice GI-24 interstadial, while the younger one to the W-22 and GI-23. Only in Western Europe this cooling has the rank of a stadial (between the Amersfoort and Brørup *sensu stricto*). In European pollen records, Brørup *sensu lato* is separated from the Eemian by a stadial (Herning or Melisey I), which usually is correlated with the marine C-24 and Greenland GS-25 stadials. However, in both marine and ice cores there is one more stadial (C-25 or GS-26) and interstadial (GI-25 or W-24) between the Eemian and the Brørup *sensu lato*. Unfortunately, these events are not reflected in the stratigraphic patterns of Central Europe, including Poland. Meanwhile, in many pollen profiles from this region, a temporary cooling was noted in the final part of the Eemian followed by an improvement in climate at the very end of the interglacial, just before the transition to the Early Weichselian. This cooling, as shown by its palynological record, has a lower rank than cooling during the Herning stadial, and is recorded only in profiles developed with high stratigraphic resolution. In pollen profiles it is commonly included to the Eemian, and the Eemian/Weichselian boundary is set only above the subsequent warming. This cooling can be correlated with the C-25 and GS-26 stadials, while the warming terminating the terrestrial Eemian with the W-24 and GI-25 interstadials. On this basis, it can be hypothesized that the upper boundary of the Eemian in pollen diagrams of Central Europe is not synchronous with the upper limit of this interglacial in the marine and Greenland cores, and this shift is approximately 8,000 years.

Coastal progradation associated with sea-level oscillations in the later phase of the Last Interglacial period, central Japan

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Stratigraphic records of minor sea-level highstands in Marine Oxygen Isotope Stage (MIS) 5c and 5a are valuable archives of late Pleistocene sea levels and paleoenvironments, but have been identified less commonly in siliciclastic coastal systems than the highstand of MIS 5e. In the Kanto Plain, central Japan, the Iioka terrace comprises the seaward margin of the uplifted Last Interglacial (MIS 5) marine terrace. Sedimentological characterization, post-infrared infrared stimulated luminescence (pIRIR) dating, and tephra and paleontological analyses of the Iioka terrace allow identification of a wave-dominated coastal sedimentary system that prograded onto the Pliocene-Pleistocene basement during MIS 5c and 5a. The pIRIR ages of the coastal deposits range from ca. 80 to 112 ka and define a seaward younging trend, which is corroborated by the seaward lowering of the terrace surfaces. In an outcrop in the seaward part, two pIRIR ages were obtained above and below the tephra layer On-Pm1 (95.7 ka), supporting the general validity of the pIRIR chronology. The elevation of beach facies in the landward part (ca. 53 m above the present sea level) abruptly lowers (to ca. 37 m) and is further truncated by fluvial incision in the seaward part. The pIRIR ages include uncertainties that prevent distinction between MIS 5c and 5a. However, the abrupt and large gap in the beach levels between the central and seaward parts suggests the presence of a minor unconformity between MIS 5c and 5a; contemporary uplift may account for the gap. The Iioka terrace is thus interpreted as representing the successive downdip accretion of depositional sequences controlled by relative sea-level changes in the later Last Interglacial period. The refined characterization of the Iioka terrace allows reevaluation of the tectonic uplift rate of this area as ca. 0.7 mm/yr, twice the rate assuming correlation of the deposits with MIS 5e. Such refinement is likely elsewhere if marginal marine terraces are characterized in detail, as carried out here.

A new Middle-Late Pleistocene succession from the southern Dardanelles (Turkey) sheds lights on the Mediterranean-Black Sea gateway evolution

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The Mediterranean-Black Sea gateway region consists of a complex set of basins (Aegean basins, Marmara Sea) and sills (Bosporus, Dardanelles, South Aegean threshold) that have a dynamic connection and isolation history impacting marine and terrestrial ecosystems in the Eurasian transition region during the Quaternary. Within the gateway region very few successions exist that enable the construction of a chronology of connection and isolation. Gateway configuration is impacted by both global sea level trajectories and regional tectonic modifications. Here we record a succession of marine and terrestrial deposits in the southern Dardanelles gateway region in western Turkey that constrain periods of connection and isolation during intermediate low stand- and high stand time intervals of the late Middle and Late Pleistocene (MIS9-MIS4). We describe five unconformity bounded stratigraphic units in three sections that form part of a coastal section north of Çanakkale (western Turkey). Twenty U-Th analyses provide age estimates for the units. Combined with facies and faunal analyses the presence of marine conditions during relative low stands of MIS6 and MIS5a-d time intervals is shown. The presence of marine intervals representing sea level low stands at or above today's sea level shows severe uplift rates in the Dardanelles threshold region in the latest Pleistocene enabling the rare exposure of these successions. Our findings also clearly indicate an important role of gateway tectonics in the connectivity history of the Black Sea-Mediterranean region in addition to eustatic sea level trajectories. The newly reported Dardanelles successions provide further age constraints of Black Sea – Mediterranean connectivity during the Late Quaternary. This study was sponsored by the Scientific and Technical Research Council of Turkey (TÜBİTAK research grants ÇAYDAG116Y541).

Disentangling the depositional systems and ecosystem evolution of the southern North Sea Basin during MIS5.

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Nearshore marine stratigraphic records in shelf areas are subject to intense reworking resulting in very incomplete, mixed and biased understanding of the evolution of depositional systems and biota. The southern North Sea Basin (SNSB) is a shallow shelf sea located south of the glacial advances that during glacial low stands became emerged. Much of the successive marine and coastal records have been reworked during glacial low stands destroying most of the Quaternary successions. Marine-coastal deposits of the Last Interglacial maximum (MIS5e: Eemian) are widespread in the subsurface of the SNSB, but deposits for the entire MIS5a-d interval (Early Weichselian) are reworked hampering our understanding of landscape and ecosystem evolution in this transitional time interval. However, the presence of deep river valley and estuarine channel systems has provided local preservation traps that contain MIS5a-d successions, even though these records also experienced different grades of reworking and mixing. Here we investigate and disentangle mixed MIS5 successions within a MIS6-MIS5 fluvial to tidal inlet in the Netherlands and a drowned MIS6 River Valley System on the Belgian continental platform in order to understand the evolution of coastal and shallow marine depositional systems, ecosystems and landscapes in the SNSB. Within a seismic/sedimentary facies framework we distinguish different provenance of mixed faunas using preservation characteristics, and ecological and stratigraphic compatibility criteria. The unmixed faunas show a succession of warm temperate to subarctic conditions and different paleoenvironments with strong biotic turnover related to sea level trajectories and paleogeographic connectivity of the North Sea in the MIS5 time interval, a period for which very little is known so far. The approach to target preservation traps and disentangle mixed records based on fossilization and other criteria is novel and applicable to shelf areas worldwide in order to investigate low-intermediate high stand time intervals.

Constraining stratigraphic age and paleoenvironments in submarine sand extraction areas: context for the rich fossil findings from nourished Dutch beaches

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Major sand nourishments serving to enhance coastal safety and expand land surface area for port development in the western Netherlands are among the most important locations for late Quaternary fossil and artefact finds world-wide. The finds may provide insight into the mammoth steppe faunas, faunal-hominine interactions and Paleolithic and Mesolithic hominin behavior, but interpretation is cumbersome.
The sand used for the nourishments is extracted offshore in the North Sea from submarine extraction pits below ~20m water depth. These archives of late Quaternary associations, palaeoenvironments and hominine behavior are now exposed on accessible beaches, where a large community of collectors and citizen scientists help to gain important insights. However, linking this now ex-situ natural history archive to the geological context has been problematic due to poor knowledge of the late Quaternary stratigraphic successions in the offshore extraction area, the severe reworking and erosion of these successions during lowstand phases and problems with radiocarbon ghost ages (finite ages of 25 - 50 ka BP for material that is much older).
Here we present sedimentary facies and fossils from a series of continuous cores obtained from the flanks of an offshore extraction pit west of Rotterdam. We define stratigraphic units, allowing us to link fossils and artefacts found on the nourished beaches to specific stratigraphic units. A large set of luminescence age estimates provide age constraints for the units.
A succession of units covering MIS6 to MIS1 is shown, and major hiatuses are identified. The succession provides new insights into the critical MIS5d-MIS5a (Early Weichselian) time interval and includes a unit that contains an in-situ cold-boreal marine fauna. The new age-constrained stratigraphic successions provide important new insights into the origin of so-called walrus faunas and mammoth steppe faunas and their depositional context. These insights are imperative to improve our understanding of the origin and age of the very rich fossil fauna and artefacts from the nourished beaches and the late Quaternary landscape and ecosystem evolution of the southern North Sea Basin.

MAGY project: MAllorca hydroloGY over the last few centuries. Instrumental validation of speleothem archives.

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Geochemical analyses of speleothems and cave monitoring offer a complete framework for cave systems concerning hydrological changes and climate variability at very different timescales. In this regard, one critical target becomes the period when paleoclimatic records overlap with the directly measured instrumental records of climate. In order to improve the interpretation of speleothems as paleoclimatic records and therefore elucidate past climate changes in the western Mediterranean region, the MAGY project intent is the comparison of a new collection of speleothem records from Mallorca Island, which spans the last centuries, with precipitation and temperature data acquired in the weathering station from the Mallorca airport. This information is particularly critical on this island which is likely to face high hydrological stress under the current conditions of climate change. The implementation of this study requires high-resolution trace element profiles obtained by LA-ICP-MS to detect even seasonality variability in the speleothems and parallel well-resolved age models. The combination of U/Th dating, the ^{14}C technique, and the confocal laser scanning microscopy technique, which allows annual layer counting, will provide solid chronologies. Preliminary results show that the Mg/Ca signal corresponds with the precipitation patterns recorded by regional instrumental records.

Poster - sessions 13, 15, 18, 147, 157, 208

Dansgaard-Oeschger climate oscillation during the early MIS3 in Europe: evidence from a multi proxy speleothem record in Han-sur-Lesse, Belgium

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Speleothems are precious continental records in Europe and provide important climatic information at high resolution, such as during the Dansgaard-Oeschger (DO) events . However, the north central Europe is less studied because the MIS 3 is generally not recorded, due to the climatic conditions. Here, we present the first Belgium continuous speleothem (flowstone) record covering the early MIS 3 (from 60 to 40 ka) from the Verviétois Gallery that is part of the Han sur Lesse cave system (southern Belgium). High resolution bulk stable isotope and elemental combined with U-Th dating are used to define the Belgium climatic variability. Additionally, clumped isotope measurements have been performed to reconstruct temperature to better constrain climatic response during the DO 16-12.
The multiproxy approach used to investigate the speleothem record shows a regional response to the global climate conditions during MIS3. The $d^{13}C$ and $d^{18}O$ values as well as the elemental analyses (Mg, Ba and Sr as water availability proxies and P and Zn as soil development) mirror the DO 16 and 12 events indicating dry-wet and cold-warm changes. During interstadials events low values of $d^{18}O$ and $d^{13}C$ and Mg, Ba and Sr content suggest wet/warm conditions, while the increase of isotopic and elemental values during the stadials support a climate deterioration with cooling and drier conditions. The clumped-isotope temperatures, performed at high resolution on the DO 16 and 12, suggest warm interstadials ($12^{O}C$ +/- $2^{O}C$) and cold stadials ($7^{O}C$ +/- $2^{O}C$) climate. During the DO12, a delay in the climatic amelioration and the vegetation is observed. This delay, also noted in south-west France cave (Villars cave), seems to be linked to a delay between increase of temperature and water availability allowing the soil above the cave to growth. Also, a climatic deterioration occurred after the DO11, with an increase time lag from the north to the south of Europe, suggesting a progressive cooling to the south Europe. It is interesting to note that this gradual cooling in Europe coincides, withing dating error bars, with the potential progressive north-south decline of the Neanderthals in Europe.

Temperature response in East Central Europe to North Atlantic interstadial warming over the 26-31 ka period

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The last glacial period (115–11.7 ka) was characterized by extensive high to mid-latitude ice sheets, low carbon dioxide (CO_2) concentrations, sea levels and global mean surface temperatures, with the most pronounced global cooling of 4−5 °C occurring over the Last Glacial Maximum (26–19 ka). However, this generally cold glacial climate was perturbed by numerous rapid shifts to milder interstadial conditions, called Dansgaard–Oeschger (D–O) events or Greenland Interstadials (GI). In Greenland, air temperatures during D–O events rose by 5–16 °C within decades, followed by a less rapid temperature decline back to stadial conditions. Around Europe, interstadial warming of 2–6 °C in sea surface temperatures (SST), corresponding to last glacial D–O events, is recorded in marine sediments and the effects of D–O events also extended across much of continental Europe and western Asia, reflecting profound changes in ecosystems and glacial atmospheric circulation. A major impediment to resolving the cause and geographical propagation of D–O events, as well as to understanding their impact on continental climates and environments, is a lack of precisely dated continental records of quantitative paleotemperatures from this time period, especially in Eastern and East Central Europe. Here we present land snail shell carbonate clumped isotope-based active season paleotemperature estimates and $\delta^{13}C/\delta^{18}O$-based aridity reconstructions from Greenland Stadial/Interstadials (GS/GI) between 31 and 27 ka from the ^{14}C-dated Dunaszekcső loess section (Hungary). This reconstruction is complemented with a new ^{230}Th-dated flowstone stable isotope record covering 30−26 ka. Our snail shell clumped isotope (Δ_{47}) data indicate growing season temperatures of 16−18 and 7−14 °C for the investigated interstadials and stadials, respectively. Stable carbon and oxygen isotope compositions of shells and flowstone calcite reveal milder interstadials with drier summers and more available moisture over the winter season, and colder stadials with annually/seasonally (winter) drier conditions, promoting increased loess/dust deposition. We propose that large scale ocean-atmospheric variability may have imparted a major control on transmitting abrupt North Atlantic climate event signals into continental Europe during the last glacial.

Dansgaard-Oeschger physics controls the Younger-Dryas Preboreal transition

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The Younger Dryas (YD) represented a rapid return to glacial conditions which occurred between 12.9 ka and 11.7ka. The rapid entrance into the YD has been conclusively demonstrated to have been caused by a release of meltwater from proglacial lakes into the Arctic Ocean through the Mackenzie River outlet. This freshwater was transported to sites of North Atlantic Deep Water (NADW) formation where it caused a pronounced slowdown of the Atlantic Meridional Overturning Circulation (AMOC). The recovery from the YD led to a series of climate variations known as the Preboreal Oscillation (PBO). This event was equally rapid but is as yet unexplained. Previous attempts to model the YD have all had inaccuracies, such as having been based upon incorrect boundary conditions, releasing volumes of freshwater that violate eustatic sea level (ESL) constraints, and failing to couple the ocean model to an appropriate atmospheric model. Using the University of Toronto version of CCSM4, we model the YD using appropriate boundary conditions, as well as a volume of freshwater forcing that is compatible with not only the ESL constraints but also the much more stringent constraints imposed by estimates of the volume of proglacial lakes. We find that the approximately 1000-year duration of the YD arises naturally. Equally important, we recover the rapid return to deglacial conditions as well as a pronounced overshoot of AMOC strength, which could potentially lead to further climate fluctuations that characterize the PBO. Equally important, is the observation that the recovery from the YD occurs in precisely the same way as it has been argued that the transition from stadial to interstadial conditions occurs during Dansgaard-Oeschger events: intense vertical mixing below the sea ice causes a massive polynya to open in the Irminger Sea. This allows for a dramatic exchange in heat between the ocean and the atmosphere, which rapidly warms the Northern Hemisphere.

Abrupt Ice Age Climate Variability: Deterministic or Random?

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Complex coupled climate models that simulate ice age climate are now able to simulate millennial time-scale Dansgaard-Oeschger (D-O) oscillations that agree well with observed proxy climate records. Whether D-O events are random or part of an internal climate system oscillation, modelling studies suggest that they can be modulated under changes in internal and external forcing such as atmospheric carbon dioxide concentration and the Earth's orbitally controlled insolation. Regularity in the pacing of D-O events may be part of an oscillatory behaviour that can exhibit cyclicity when a control parameter (associated with internal or external forcing) passes through a critical point which results in an unstable oscillatory state. Nonlinear dynamical systems used to emulate D-O oscillations are very sensitive to noise, and transitions between warm and cold states may be caused by noise perturbations possibly associated with internal climate variability. Possible mechanisms associated with noise induced D-O transitions (such as volcanic forcing) will be discussed in an effort to shed light into the erratic signal observed in ice age climate records.

Early warning signals in model simulations of spontaneous Dansgaard-Oeschger type events.

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Much progress has been made recently in understanding the physical mechanisms underlying Dansgaard-Oeschger events, with a consensus developing around the centrality of changes to the Atlantic Meridional Overturning Circulation (AMOC). What triggers these changes, however, remains unclear, with sea ice coverage, atmospheric patterns, or freshwater forcing all considered potential causes. An interesting question here is whether DO events are induced by a bifurcation in the dynamical system or simply by noise. The answer to this question would reveal much about the potential range of physical causes of these events, providing a focus for future work. To probe this question, we can search for Early Warning Signals (EWS) prior to DO events in the form of increased variance and autocorrelation within the decadal frequency band associated with a critical slowdown. Such EWS, if found, would be compelling evidence that there is an underlying bifurcation. Previous research has shown some EWS in ice core derived temperature proxy records for Greenland, however this is not universally agreed. Here we perform such analysis on output data from climate models which show spontaneous oscillations in AMOC resembling DO events, allowing investigation of a wider range of physical variables and spatial locations than are recorded in proxy data. As well as providing insight into the dynamics of DO events as they occurred in the past, this also provides a useful test of how effectively these models capture the relevant physical mechanisms.

Control of ice sheet configuration, atmospheric CO2 and orbital forcing on millennial-scale climate variability in an Earth system model

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Dansgaard-Oeschger events are a ubiquitous feature of glacial climates involving abrupt and large changes in climate, particularly over the North Atlantic region. A number of climate models, under particular boundary conditions, have been able to reproduce various aspects of these rapid climate changes, suggesting that they could be the result of internal oscillations in the climate system.

Here we use the fast Earth system model CLIMBER-X to explore ice sheet configurations, atmospheric CO2 concentrations and orbital parameters that are favorable to the existence of self-sustained oscillations.

We find that for ice sheet configurations corresponding to intermediate glacial conditions and for a range of CO2 concentrations between 160 and 200 ppm, the model produces spontaneous millennial-scale oscillations that resemble observed Dansgaard-Oeschger events. The oscillations involve rapid changes in the location of deep water formation and strength of Atlantic meridional overturning circulation, with pronounced effects on climate in the North Atlantic region and beyond.

Millenial-scale oscillations of lower amplitude are simulated in the model also with present-day ice sheets with sufficiently low CO2 concentrations, while the large ice sheets of to Last Glacial Maximum act to largely suppress the spontaneous oscillations.

In our simulations, the orbital configuration has a relatively minor effect on simulated millennial climate variability.

Global footprints of Dansgaard-Oeschger oscillations in a GCM

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We have identified Dansgaard-Oeschger (DO)-like millennial-scale climate variability in a glacial simulation based on the salt oscillator hypothesis with the HadCM3B coupled atmosphere-ocean-vegetation model. The simulated DO-like warming shows temperature changes of 7.1 ± 2.5°C in Greenland, comparable to DO9 or DO6, the smallest temperature changes of the observed DO events. This presentation focuses on the impacts of DO-like events on climate and vegetation beyond the North Atlantic. We find that the simulated warming in the Northern Hemisphere extratropics during Greenland interstadials largely agree with available proxy estimates. The simulated tropical hydroclimatic responses during the interstadials, such as northward propagation of the Intertropical Convergence Zone, strengthening of some Northern Hemisphere summer monsoons, and weakening of some Southern Hemisphere monsoons, are also roughly consistent with proxy estimates.

Moreover, simulated vegetation cover increases in the Northern Hemisphere during interstadial relative to stadials, while no large-scale dominant vegetation changes are consistent with observed biome changes associated with observed DO6. To further assess detailed vegetation responses and fire effects in DO-like cycles, we run the LPJ-LMfire dynamic global vegetation model (DGVM) and test differences with the TRIFFID DGVM.

Our simulation based on the salt oscillator hypothesis can account for many observed features of DO events. However, it cannot simulate several observed climate responses in the equatorial Indian and western Pacific Oceans, including the East Asian and South African monsoon. The causes of those mismatches need to be further explored, whether they are hypothesis-dependent or model-dependent.

Rapid atmospheric CO2 rise during Heinrich Stadials and Dansgaard-Oeschger Events

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The impact of Heinrich Stadial (HSs) and Dansgaard-Oeschger (D-O) events on global atmospheric CO_2 concentrations (pCO_2) was previously thought to be negligible. This traditional viewpoint was upended with the recent discovery of centennial-scale rises in pCO_2 during HSs and D-O events (Bauska et al. 2021). The newly resolved pCO_2 record sheds critical light on carbon-cycle variability during these rapid climate shifts, yet the exact rate and magnitude of pCO_2 remains a topic of debate. This study aims to examine pCO_2 variations at sub-centennial scale resolution in order to fully resolve pCO_2 variability during HSs 2-5 and D-O events 3-18. To do so, we sub-sampled the West Antarctic Ice Sheet Divide ice core (WDC) down to 5-year resolution along select depth intervals. Measurements were replicated to within an average standard deviation of 1ppm. Preliminary results show an average rise of ~10 ppm pCO2 that coincides with the mid-stadial rise in atmospheric methane associated with HSs 2-5 (Rhodes et al., 2015) following the onset of stadial conditions in the Northern Hemisphere. The largest increase in pCO_2 is associated with HS4, during which pCO_2 rose 17 ppm from 39.58 to 39.47 kyrs before present on the WD2014 chronology. Lower-magnitude rises of ~5 ppm occurred at the abrupt warming of most D-O events. The difference in magnitude between stadial versus interstadials point to separate mechanisms operating under distinct climate modes. Additional sampling is currently underway to further investigate rapid pCO_2 changes linked to abrupt shifts in North Atlantic climate.

Bauska et al. (2021) Abrupt changes in the global carbon cycle during the last glacial period. *Nature Geoscience* **14** 91-96.

Rhodes et al. (2015) Enhanced tropical methane production in response to iceberg discharge in the North Atlantic. *Science* **348** 1061-1019.

Changing sea ice distribution in the northern Nordic Seas over GS-9 and GI-8

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The sediment core MD99-2304, retrieved from the eastern Fram Strait (1300 m water depth; 77°37'15.6"N, 9°56'54.0"E), is analyzed for biomarkers in high-resolution (ca. 20 years/sample) over stadial (GS-9) and interstadial (GI-8). The results document changes in sea ice dynamics between 40 and 37 b2k with unprecedented detail. The combined results of IP_{25}, HBI III (Z-isomer) and sterols suggest that a seasonal to long-lasting sea ice cover dominated the northern Nordic Seas during the stadial, with possible opening of polynyas. The existence of polynyas in the Fram Strait during stadial conditions is also found in a freshwater forced transient model run of the Norwegian Earth System Model (NorESM). The sea ice in this region started to retreat within GS-9, likely related to the accumulated ocean heat reservoir, and the sea ice extent decreased sharply at ca. 500 years before the end of the stadial, as defined from NGRIP. At the start of GI-8, the sea ice cover expanded rapidly and returned to similar sea ice condition as seen early in GS-9. The early decrease in the northern sea ice cover emphasizes the importance of sea ice dynamics for the abruptness of the Dansgaard-Oeschger events. The new results from the Fram Strait will be discussed in context of existing sea ice records from a transect of sediment cores along the eastern Nordic Seas. It is indicated that in the late phase of GS-9, polynyas may have already existed in the north when the open ocean associated with the recovery of the warm Atlantic Water started to erode the sea ice cover from the south, since the pelagic phytoplankton in the north bloomed ca. 300 years before fully open water conditions are documented in the south.

Multi-tracer(2H, 3H, 13C, 14C, 18O, 39Ar, 81Kr, Noble gases) study-Groundwater dating and paleoclimate reconstruction in Leizhou Peninsula, South China

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Groundwater is a key water source for natural environments and human society, detailed knowledge about the groundwater system is necessary, especially under global change. Groundwater residence time, or so-called *groundwater age*, is a very important parameter, which can be used for the assessment of groundwater renewability and sustainable development. In addition, groundwater is a natural archive of paleoclimate information, which is valuable for the understanding of climate change. In this study, we applied multiple tracers, namely ^{2}H, ^{3}H, ^{13}C, ^{14}C, ^{18}O, ^{39}Ar, ^{81}Kr, and noble gases to estimate the groundwater age and reconstruct the signals of paleoclimate, mainly the history since the LGM (Last Glacial Maximum) in the Leizhou peninsula, South China. In total, 41 monitoring wells were chosen for groundwater sampling. The dating results of ^{3}H, ^{4}He, ^{14}C, ^{39}Ar, and ^{81}Kr can corroborate each other, though, for some samples, the processes of diffusion, dispersion, and groundwater mixing may make the interpretation trickier. Most of the samples are in the dating range of ^{14}C, less than 24,000 yrsBP. Some samples with ^{14}C less than 2 pMC cannot rely solely on ^{14}C and the results of ^{81}Kr indicate quite old age. Surprisingly, both $_{39}Ar$ and ^{81}Kr are found to be significantly higher than the modern atmosphere value in some samples, which may indicate potential underground sources of them and require further research. Regarding the paleoclimate reconstruction, noble gas temperatures derived from their concentrations show that the temperature difference between LGM and modern is at least 5.4 °C, which is comparable with other studies in the tropical area. ^{18}O and 2H are more correlated with the precipitation amount than with the temperature. Besides, the paleoclimate signals derived from the groundwater are compared with those from other local climate archives, such as the Maar lake sediment.

Palaeoenvironmental reconstruction of the LGM period in the Upper Dnieper basin (Ukraine) based on multi-proxy analysis of the youngest loesses

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The youngest loess cover of the Ukrainian part of the Upper Dnieper basin belongs to the northern fragment of the European loess belt developed both as a continuous cover and as isolated ‘islands’ located in the foreland zone of this belt. The litho- and pedological development, similar thickness (4-5 m), age (~28-15 ka) of the upper, near-surface part of these covers, i.e. the Bug loess (MIS 2), are its common features. The subject of the palaeoenvironmental studies are key loess sites in a meridional arrangement. These profiles were analysed based on the results of, inter alia, physico-chemical studies, spectrophotometric studies, magnetic susceptibility anisotropy and luminescence dating. In terms of litho- and pedological formation, the studied profiles have the character of loess-paleosol sequences, in which loess bg (=L1LL1), formed after the end of loess- and soil-forming processes during MIS 3.

The starting point for the environmental analyses were spectrophotometric and grain size measurements. The first reflect the colour parameters, while the second reflect the size of the elementary particles. In the light of the measurements, the litho- and pedological development shows a number of specific features related to the syn- and postdepositional evolution of the environment. The colour parameters correspond to the pigmentation occurring during the epigenetic stage, while the granulometric parameters mainly record the characteristics of the sedimentary environment. In the spectrophotometric images of the individual samples, as well as in the shapes of the lines of variation of the granulometric indices and in the heat maps, specific patterns of change corresponding to climate oscillations are noticeable. In the spectrophotometric images, as well as in the shapes of the lines of variation of the granulometric indices and in the heat maps, specific patterns of change are noticeable. These changes correspond to global climate oscillations and can also be very local.

Research carried out as part of the grant of National Science Centre, Poland (the project no. 2018/31/B/ST10/01507) entitled “Global, regional and local factors determining the palaeoclimatic and palaeoenvironmental record in the Ukrainian loess-soil sequences along the Dnieper River Valley - from the proximal areas to the distal periglacial zone”.

Deglacial history of the Kattegat-Baltic Sea using x-ray micro-computed tomography of benthic foraminifera

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The Baltic Sea is strongly affected by the combined stressors of deoxygenation, acidification, and eutrophication. These are primarily derived from 1) anthropogenic CO_2 emissions, which increase atmospheric temperatures, enhance surface water stratification, reduce oxygen solubility, and alter carbonate chemistry, and 2) nutrient pollution from the Baltic Sea's heavily populated coastline. Together, these rapid environmental changes are significantly impacting fragile coastal ecosystems and dependent economies, yet the combined effects of multiple stressors are still not well understood. Paleoceanographic reconstructions of the Baltic Sea from past periods of rapid warming can provide benchmarks for and help predict future synergistic effects of multiple stressors as well as regional oceanographic responses to changes in global climate.

Our research uses a continuous, high-resolution sediment record of the last deglaciation (~18-15 ka) from the Kattegat seaway between Sweden and Denmark (IODP Expedition 347 Site M0060). Existing results for M0060 from benthic foraminiferal stable oxygen and carbon isotopes, trace elements, species assemblages, and a recalibrated age model support evidence of an early deglacial, poorly ventilated setting that undergoes freshening until ~15.5 ka, concomitant with the retreat of the proximal Fennoscandian Ice Sheet (FIS), followed by a transition to better ventilated, more saline conditions. We use synchrotron-based x-ray micro-computed tomography of benthic foraminiferal species *Elphidium clavatum* at decadal- to centennial-scale resolution to generate three-dimensional shell morphology (e.g., shell thickness, density, porosity, surface area/volume ratio). These morphometrics are expected to reflect bottom water environmental changes, likely controlled by the combined influence of adjacent FIS dynamics, European continent glacial meltwater, and North Atlantic circulation. Quantifying morphometric variability across the deglaciation will further constrain end-Pleistocene changes in temperature, oxygen, salinity, carbonate chemistry, and productivity, as well as disentangling the relative controls of regional ice-sheet and climate dynamics on the Baltic Sea from larger North Atlantic climate.

Impact of Climate Change on Gas Hydrate Stability Zone due to Progression of Bottom Water Temperatures in the Krishna Godavari Basin.

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Gas hydrate dissociation acts as a primer/trigger for many historical landslides due to changes in temperature, pressure, salinity, etc. Gas hydrates are more sensitive to Temperature change than to pressure. The 3D seismic data from a small region in the Krishna Godavari basin is examined in the present study to understand the dissociation mechanism of the gas hydrates. Seismic Interpretation reveals that the Bottom simulating reflector (BSR) is shoaling upwards and truncating near the seafloor creating slope failure. The reason for the shoaling of BSR is examined and found that the Bottom water temperature is a critical parameter for causing the shift in BSR Post-Glacial maximum. The hydrate stability zone during the Glacial time (seafloor temperature 4 °C) and the present day (seafloor temperature 6.5°C) is computed with varying geothermal gradients (GTG) of 45 + 3° C per km observed from well log data of NGHP-01-10A lying close to the study area. It is observed that the Base of the hydrate stability zone (BSR) shifted by 80 meters post-glacial at 1000 meters of water depth. Changing the GTG has caused only a ten-meter change in the shift but changing the seafloor temperature has caused 80 meters shift in the BHSZ.

Quaternary terrace deposits in the Apulia region (southern Italy): an archive for the reconstruction of palaeo SSTs and Meditterranean pressure pattern during the last interglacial.

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Terraced deposits associated to palaeoshorelines in the Apulia region (southern Italy) proved to be a useful palaeoclimatic archive.

In the area of Gallipoli, the aeolian units AU1 and AU2 present within *Il Carmine-Li Foggi* paleo littoral ridge and the aeolian unit AU3 which outcrops in the *Il Campo* locality allowed us to reconstruct the paleo-directions of the winds and the atmospheric pressure patterns during MIS 5.5. AU1 is the first unit to settle and indicates a "first aeolian phase" of MIS 5.5, characterised by a NW-S bimodality of the winds, which involved fall-winter and spring-summer pressure patterns similar to the current ones, with a spring-summer not very effective for the aeolian transport and an autumn-winter characterised by an Atlantic footprint effective for the aeolian transport by the onset of winds from the S and NW which alternate following the transit of pressure lows from Atlantic across the Mediterranean.

AU2 and AU3 settled later than AU1, in a "second aeolian phase" of MIS 5.5, characterised by a prevailing NW wind regime. AU2 and AU3 settled under a pressure pattern similar to the current one in fall-winter, but characterised by a pressure gradient from west (high) to east (low), in the spring-summer, much stronger than the current one. This regime caused summer NW winds stronger than today and effective for wind transport. These strong NW winds in summer, coupled with the NW-S bimodality in fall-winter, caused the overall prevalence of NW winds during the "second aeolian phase". This summer pressure gradient on the Mediterranean greater than today was caused by a summer strengthening of the east Mediterranean low-pressure, in turn caused by the northward shift of the ITCZ, widely documented during the Sapropel S5 event, occurred during the MIS 5.5 after sea level had risen to the highstand.

On the other and, marine terrace deposits dating back to MIS 5.5 and MIS 7.3 near Lizzano, both containing *Cladocora caespitosa*, allowed us to reconstruct palaeo SSTs of these two stages thanks to several palaeo temperature proxies provided by this coral. Our reconstruction highlights a different warming of coastal waters during these two stages.

Late Pleistocene- Holocene boundary: A preliminary study of paleoceanographic conditions at the Santos Basin, São Paulo, Brazil

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In April of 2022, a teaching and research expedition reunited young scientists and graduate students to gather data and study the geology and geophysics of the continental shelf and slope of the Santos Basin (24°S/44°W). Prolonged exposure to the continental platform during past glacial stages may have influenced paleoecology and sediment deposition. Therefore, this study aims to understand changes in this region's climate and oceanographic circulation since the Last Glacial Maximum (LGM). The gravity corer drilled five cores at least three meters long of continuous marine sediments. Lithological description followed the facies analysis. Mass normalized magnetic susceptibility was measured using the Kappabridge MFK1-FA (AGICO) in 2 frequencies: 976 Hz and 15616 Hz. Samples for micropaleontological analyses were wet-sieved in a >63 µm mesh and dried at 50°C. The assemblages of planktonic foraminifera were performed through a binocular microscope. The preliminary results show that the five studied cores are mainly composed of clay minerals with fine-grained sediments, detrital siliciclastic grains, and carbonate microfossils. The major species of planktonic foraminifera found were: *Globigerinoides ruber, Trilobatus trilobus, Globorotalia menardii, Neogloboquadrina dutertrei, and Globorotalia crassaformis*, which are characteristics of warm and transitional waters. Most core tops identified the biostratigraphic biozone X associated with interglacial climates. At the cores C1GC1, GC03, C3GC3, and C2GC3, the last glacial Biozone Y (the Last Glacial Maximum, LGM) was identified by the lack of subtropical and transitional climate foraminifera. At the bottom of the core GC03, the high abundance of *G. menardii* indicates the interglacial Biozone X. The magnetic susceptibility results mostly agree with the lithology and sea-level fluctuations, showing higher values in a sandy mud substrate, perhaps due to higher terrigenous input at transitioning (interglacial-glacial) climates. The Field dependent susceptibility has most of the values ranging from 2-10%, suggesting a mixture of Superparamagnetic (SP) and coarser non-SP grains. Thus, this consistent signal throughout the cores suggests that the differences seen in the lithology are closely related to sea-level fluctuations rather than differential input sources in the area.

Keywords: Santos Basin, Foraminifera, Magnetic Susceptibility, Last Glacial Maximum.

Multi-sensor core logging (MSCL) data of Marine Cores from Santos Basin (São Paulo, Brazil): A Preliminary Analysis

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The Pleistocene-Holocene paleoceanographic variability recorded in South Atlantic sediments is less well documented and understood compared to North Atlantic sediments. Therefore, in April 2022, an oceanographic expedition at the Santos Basin recovered marine sediments from the Pleistocene-Holocene boundary. The Santos Basin is located on the Brazilian southeast-south continental margin between 23ºS and 28ºS, its lithology is characterized by fine sand and silt in the middle and outer portions of the shelf. This study aims to reconstruct the paleoenvironment from the physical properties of 4 cores drilled near the Santos slope. The cores working halves passed through a Geotek MSCL (Multi-Sensor Core Logger) automated instrument for measuring the physical properties of the sediment (gamma ray attenuation, gamma natural, P-wave velocity, magnetic susceptibility, density), with a spatial resolution of 0.5 cm. The data were further processed to attenuate the spiky profiles resulting from the instrumental acquisition that was set up with a relatively low counting time (1 s). A slight data smoothing was achieved by a 3-point running average after removing all existing anomalously low/high values. The MSCL data provided the following characteristics for the analyzed marine cores: a relatively high density; low porosity; low-to-mean natural gamma count; high susceptibility; and low-to-mean resistivity. The density changes abruptly following the magnetic susceptibility. These changes in density may be indicating changes in material composition as variations in clay content. The high magnetic susceptibility may be an indication of a clay matrix that has magnetic elements such as iron present within the clay or other elements such as pyrite. Resistivity measurements are low suggesting the clay-rich sediments. MSCL data show us a very low natural gamma profile indicates sediments with lower clay content. We observes an increase in natural gamma, density, and magnetic susceptibility resulting from an increase in grain size in some intervals. For better correlation, we intend to perform geological and lithological descriptions of the marine cores facies to identify with precision the lithological boundaries.

Keywords: Pleistocene-Holocene, Santos Basin, MSCL, Magnetic Susceptibility

Late Glacial to Holocene transition: the story told by subfossil Cladocera remains (Żabieniec Mire, Poland)

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One of the most discussed research topic in Earth sciences at present is contemporary climate change. Paleogeographic study allow to recognize and reproduce changes in environmental conditions over past geological eras. In a time period from the Late Vistulian (the youngest part of the last glaciation) to the Early Holocene (the beginning of interglacial), there were periods of rapid changes in climatic conditions (coolings - stadials and warmings - interstadials). The aim of the conducted studies was to trace in detail the periods of rapid changes during Late Glacial based on subfossil Cladocera analysis. The Żabieniec site is located on the moraine plateau of the Łódź Hills in Central Poland. Biogenic sediments of more than 12 m thick have been identified with continuous accumulation since the beginning of the Late Vistulian to modern times. Sampling was performed with high resolution (1 cm), which corresponds to time intervals of about 10 to 20 years. Such approach allowed to set up borders between stadials and interstadials of Late Glacial.

The fluvial influx and upwelling changes off Saurashtra coast during the Late Quaternary.

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The climate of the Indian subcontinent is mainly determined by the Arabian Sea and the Bay of Bengal. The sediments of the Arabian Sea are widely used for the reconstruction of past variability in Indian Summer Monsoon (ISM) and coastal upwelling. For the present study, we used 4.30 m core samples SK240/473 from off the Saurashtra coast with a water depth of 121 m. This study aims to understand the weathering response of the Himalayas to climate forcing during the late Quaternary by using relative abundances of Planktonic foraminifera *Globigerina bulloides* and the Ratio of *G.bulloides/G.ruber*. *G.bulloides* is the asymbiotic species commonly seen in transitional to polar, but it is also characterized in nutrient-rich upwelling areas. The relative abundance of *G.bulloides* varies between 35 % to 4% and the ratio changes between 0.1 to 2.5. The *G.bulloides/ G.ruber* ratio and *G. bulloides* abundance show a positive correlation, where its abundance indicates high productivity in the area. The high value of *G.bulloides/ G.ruber* in two depths (302 cm and 316 cm) indicates a period of intense upwelling, which coincides with high benthic percent. In section, I, a period of low *G.bulloides/G.ruber* ratios would indicate lower production and the influence of warm, oligotrophic water. The depth range of 140 cm to 430 cm (II section) denotes periods of strong productivity, as well as the influence of cold, nutrient-rich water. As a result of the data, we can deduce that this site has a period of low production up to 140 cm, after which the rate of terrestrial input and upwelling doubles. Also, past weathering regimes are important for a better understanding of the influence of climate on weathering in the study area.

A novel East Asian Summer Monsoon index reconstructed from a mixed approach and the multidecadal variability revealed in the1400-1900s

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The East Asian summer monsoon (EASM) is a distinctive component of the Asian climate system due to orographic forcing. Unlike Indian summer monsoon which occurs within the South Asian monsoon trough and presents a uniformity of rainfall distribution allowing for an All Indian Rainfall index to measure its variability, the definition of the EASM intensity has been much more complicated. One of the main reasons is the extensive domain of the EASM encompassing tropics, subtropics and midlatitudes and thus the complex space and time structures making it difficult to quantify the EASM variability. Despite the challenges, studying the evolution of EASM over hundreds or thousands of years is essential to build a comprehensive understanding on the monsoon behaviors and their associations with the general circulations. Hence, many previous studies have used geochemical proxy records from oceanic sedimentary or continental archives to build paleo-EASM indices by depending on mostly rainfall information retrieved from the records at some sites. The sort of the methods inevitably faces the issue of spatial coverage and limited explanatory power for the overall EASM.

In this study, we present a novel approach to reconstruct a paleo-EASM index. First, the current observational Western North Pacific monsoon index (Wang et al. 2008, in Journal of the Climate) approach was used to calculate the wind fields (zonal and meridional winds at 850hPA) from 1950 to 2020 using ERA5 data and rainfall data from NOAA Precipitation Reconstruction over Land to construct the modern EASM index and to examine the relationships between the rainfall and circulation anomalies. Then, the EASM rainfall pattern was projected to the gridded REACHES (Reconstructing East Asian Climate Historical Encoded Series) (Wang et al., in Scientific Data) historical climate index data between 1400 and 1900s. Thus, the reconstructed REACHES EASM index considers both temporal and spatial variability. In addition, the REACHES EASM index was further examined by overlaying the data with extreme events such as flood and drought from social archives. Therefore, the indication of the dominate large-circulation is able to be investigated at the multidecadal to centennial scale at the historical time.

Abrupt global change and the East Asian Monsoon: the impact of Heinrich Event 4 and Greenland Interstadial 8 inferred from the sediments of Lake Suigetsu, Japan

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The climatic drivers controlling the Asian Summer Monsoon (ASM), which directly affects water resources and water-borne geohazards for over half of the Earth's population, are still highly debated. The long-proposed alignment between SM and high latitude climate forcing suggested by the similarities between Greenland ice core records and speleothem archives from China is increasingly challenged by terrestrial and marine sedimentary records. But there are only a handful of palaeorecords with sufficiently accurate chronological constraints to provide insights into the lead and lag of ASM variability compared to global benchmarks, such as ice core records.

The annually layered sediments of Lake Suigetsu (Japan) provide a unique opportunity to study ASM variability during periods of rapid climate change at unprecedented precision. The chronologic framework for Lake Suigetsu is an integral component of the IntCal20 radiocarbon calibration, and sampling and chronological work follows strict protocols. Lake Suigetsu's location at the western coastline of Japan's main island, Honshu, makes it sensitive to climatic influences from the north-westerly winter monsoon, and summer to autumn south-western and Pacific monsoonal influences. Here, we aim to use the Lake Suigetsu sediments to untangle rapid ASM variability during the last glacial cycle, with an initial focus on the time interval between 40 and 34 cal ka BP sampled at a temporal resolution of on average < 60 years and covering Heinrich event 4 and Greenland Interstadial 8.

Hydrologic change is reconstructed by stable isotope analysis (oxygen, carbon) of non-traditional lake sediment material, namely biogenic silica (diatoms) and early diagenetic siderite ($FeCO_3$); supported by FTIR (Fourier-Transform Infrared Spectrometry) estimates of sedimentary (mineral) composition. These analyses in concert with previously collected X-ray fluorescence and pollen data provide detailed insights into hydrologic response in Japan during an episode of abrupt global change. This includes a potential temporal mismatch with warming in Greenland in the Suigetsu record while simultaneously highlighting stronger correlations with Pacific and Antarctic climate records.

East Asian monsoon variability recorded in lacustrine sediments from the Jingpo Lake, NE China

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Abstract: The Northeastern China involves complex interactions between the East Asian monsoon (EAM) circulation and the polar climate system, and plays a significant role as the bridge communicating low and high latitude climatic processes. High-resolution pollen, grain size, magnetic susceptibility, TOC/TN mass accumulation rate (MAR), C/N ratio, and carbon isotope of organic matter data from a 11.54 m lacustrine sediment core recovered from Jingpo Lake in northeastern China provides a detailed history of East Asian monsoon (EAM) variability and vegetation changes during the Mid- to Late Holocene. The 13 AMS ^{14}C ages (nine from terrestrial plant leaves and four from bulk organic matter samples) used for the robust chronological sequence indicate that the lacustrine sediment core has been accumulated since ~5100 cal. yr BP. From ~5100 to 3600 cal. yr BP, is characterized by the highest pollen percentages of *Quercus*, *Ulmus*, *Juglans* and *Corylopsis*, low Md (median diameter) and high $\delta^{13}C_{org}$ values reflecting relatively warm and humid period. Between ~3600 and 2100 cal. yr BP, high Md and low $\delta^{13}C_{org}$ values, and the rapidly increase in herbs pollen percentages, indicating cool and dry climatic conditions. From ~2100 to 100 cal. yr BP, a gradual increase in $\delta^{13}C_{org}$ values and low Md values, and the rapidly increase in *Carpinus*, *Juglans* and *Corylopsis* pollen percentages denoting climate changed towards warmer and wetter conditions. After ~100 cal. yr BP, the highest values of TOC-MAR, TN-MAR and χ_{lf} suggesting that the Jingpo Lake region is severely affected by human activities. The EAM variability over the northeastern China during the Mid- to Late Holocene have similar trends to EAM records in China. Furthermore, our findings indicate that variability of the EAM during the Mid- to Late Holocene on multi-decadal to centennial scale are forced by changes in both solar output and oceanic–atmospheric circulations.

A 1250-year long monsoon-driven drought record from Ea Tyn Lake (Vietnam)

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The South-East Asian tropics remain severely under-represented in paleoenvironmental and paleoclimatic reconstructions, although a few recent paleoclimate studies evaluated the variability, position and strength of the main Asian monsoon systems at different timescales from modern records to the last 45,000 years. Comparable data from Vietnam, however, are scarce although Vietnam and its Central Highlands are critically located at the intersection of the East Asian Summer Monsoon and the Indian Summer Monsoon with highly important socio-ecological consequences from changes in the climate system. We here present a high-resolution sedimentary climate record from Ea Tyn Lake in the Vietnam's Central Highlands covering the last 1,250 years. Using geochemical and sedimentological proxies and principal component analysis, we reconstructed at least 12 drought events, some of which appear to be of supraregional significance as they coincide with historically documented droughts in India, China, and Cambodia. Especially the summarizing XRF-based PC2 values are in very good agreement with the Palmer Drought Severity Index (PDSI) of the region so far based on tree rings. Beyond tracking short-term climate events, the Rb/Sr elemental ratio along our lake sediment sequence reflects long-term monsoon variability throughout the last millennium, which was previously only reconstructed via δ^{18}O speleothem records from China and India. Our record shows that the East Asian Summer Monsoon was relatively strong between ~1000 and 1350 cal CE and weaker between 1350 and 1850 cal CE, followed by renewed intensification after ~1850 cal CE. Future work can extend the Ea Tyn Lake record further back in time, and studies on changes in land-cover and land-use in the Central Highlands of Vietnam may yield a clearer picture of the impact of monsoonal variability on regional vegetation.

Deciphering the influence of SST on monsoon rainfall: A combined proxy data – modeling approach

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The Australasian monsoon systems constitute central elements of the global hydrological cycle and influence the living conditions of billions of people. With respect to global future warming, it is thus an enduring issue to gain a comprehensive understanding of the regional monsoon dynamics, particularly under warm climate conditions.

Paleoclimatic data provide evidence that monsoon rainfall is influenced by varying sea surface temperatures (SST) and SST gradients, for instance in response to changing astronomical forcing. However, this connection has yet to be studied in a systematic approach. Climate model simulations provide ideal means to address the coupling between SST and monsoon rainfall and underlying mechanisms. However, the uncertainty in monsoonal rainfall simulations is still high and temperature simulation is one of the main sources of error.

To tackle this issue, we combine a network of proxy-based reconstructions of SST and rainfall amount from the Australasian monsoon realms with numerical model simulations. More specifically, we compile proxy-based SST reconstructions from the Australasian monsoon realms. We intend to analyze the spatial-temporal variability of SST (and rainfall) during the Holocene and previous interglacial periods, such as MIS5 and MIS11, from proxy-based reconstructions, and use the results as a testbed for model simulations of monsoon rainfall.

Dust impacts on paleomonsoons from CESM simulations

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Mineral dust acts both as a tracer and a forcing agent of climate change. Past dust variability, imprinted in paleodust records from natural archives, offers the unique opportunity to reconstruct the global dust cycle within a range of possibilities that plausibly encompass future variations in response to climate change and land-cover and land-use changes. Dust itself has direct and indirect feedbacks on the climate system, through impacts on the atmosphere radiative budget and the carbon cycle. Starting from well-constrained re- constructions of the present and past dust cycle, we focus on quantifying dust direct impacts on the atmospheric radiation. We discuss the intrinsic effects of dust onto climate, and how changes in the global dust budget and surface conditions modulate the effective impacts on surface temperatures and precipitation. Most notably, the presence of dust tends to enhance the West African monsoon and warm the Arctic. We also highlight how different choices in terms of dust optical properties and size distributions may yield opposite results, and what are the observational constraints we can use to make an informed choice of model parameters.

Insolation and CO2 impacts on the spatial differences of the MIS-9 and MIS-11 climate between monsoonal China and central Asia

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Marine oxygen isotope records and ice cores in Antarctica suggest that Marine Isotope Stage (MIS) 9, an interglacial occurring about 300 ka ago, is a strong interglacial and has the highest greenhouse gases (GHG) concentrations during the past 800 ka. Model results also show that MIS-9 is the warmest interglacial among the last nine ones as a result of both its high CO_2 concentration and its high summer insolation in the northern Hemisphere (NH). However, the China loess records show that the paleosol S3 that corresponds to MIS-9 is not necessarily strong as compared to some other paleosol units such as the S4 soil that was formed during MIS-11, suggesting relatively drier climate condition during MIS-9. By contrast, in Tajikistan of southern central Asia, the paleosol S3 is the most developed soil over the past 800 ka, indicating a relatively warm and humid climate conditions. The difference in the paleosol formation and the MIS-9 climate between monsoonal China and central Asia is intriguing. In this study, we combine loess records from monsoonal China and central Asia as well as climate simulation results to understand the spatial difference of the MIS-9 climate in particular in comparison with the climate of MIS-11. The individual and combined contributions of insolation and greenhouse gases are quantified through simulations with the LOVECLIM model and using the factor separation technique. Our results show that the simulated effective moisture conditions between northern China and southern central Asia are consistent with the loess records and field observation. Insolation leads to much more annual mean precipitation than GHG during MIS-9 in southern central Asia, explaining a much wetter MIS-9 there. By contrast, both insolation and GHG lead to more annual mean precipitation and evaporation during MIS-9 in northern China, leading to only a slight difference in the effective moisture between MIS-9 and MIS-11. In addition, compared to MIS-11, the higher insolation and GHG concentration during MIS-9 lead to an anomalous atmospheric circulation pattern similar to negative phase of North Atlantic Oscillation (NAO), favoring precipitation increase in southern central Asia and therefore explain strong soil development in Tajikistan.

Warming-induced northwestward migration of the Asian summer monsoon in the geological past: Evidence from climate simulations and geological reconstructions

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The cold and warm intervals during the Plio-Pleistocene provide an opportunity to assess the response of the Asian summer monsoon (ASM) to different levels of global warming. In this study, the northern edge of the ASM, a sensitive indicator of the advance and retreat of the ASM rain belt, was analyzed using climate outputs from PMIP3 and PlioMIP1, for the Last Glacial Maximum (LGM, □21,000 yr BP), the preindustrial, the mid-Holocene (□6,000 yr BP), and the mid-Pliocene (□3.3–3.0 Ma), among which the global temperature increased sequentially. The results show that the northern edge of the ASM migrated northwestward by □200 km, □50 km, and □50 km with global warming from the LGM to preindustrial, from the preindustrial to mid-Holocene, and from the mid-Holocene to mid-Pliocene, respectively. These results are generally consistent with geological records. The simulations show that the western Pacific subtropical high (WPSH) intensified and expanded geographically, and the intertropical convergence zone (ITCZ) migrated northward over the Indian Ocean and was shifted southward over the western Pacific. This led to a northwestward shift of the Asian monsoonal rain belt, and consequently to wetter conditions in India and northern China. During the mid-Pliocene, pronounced warming substantially intensified the WPSH, leading to the suppression of moisture transport from the Indian Ocean to southern China and the Indo-China Peninsula. Our results suggest that if the planet returns to a Pliocene warm world, precipitation will increase in northern China, while southern China and the Indo-China Peninsula will experience more frequent droughts.

Vegetation and hydroclimate changes in the Ganges–Brahmaputra basin since the Last Glacial Maximum

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The Bengal Fan, the largest submarine active fan in the world, is fed by the Ganges and Brahmaputra (G-B) rivers, and corresponds to the final sink for the huge erosional system draining most of the Himalayan range. Although tectonic processes mainly control long-term changes in riverine sediment flux, and associated erosional carbon burial, the intensity of Himalayan weathering on the Glacial-Interglacial timescale may be modulated by changes in climate and vegetation cover in the G-B basin. However, detailed changes in vegetation composition of the G-B hydrological basins in response to the Indian Summer Monsoon variations is cruelly lacking and remain to be documented.

Our study is based on an original approach that consists of pollen analysis of marine sediments collected in northern Bay of Bengal (16°N). Hence, pollen assemblages from the cores SO-93 represent an integrated image of the regional vegetation, and therefore climate, in the G-B hydrological basin during the last 18 kyrs.

We present herein the preliminary results of our palynological investigations. Pollen assemblages indicate the dominance of an open savannah prior to 11 ka, as evidenced by the highest percentages of arid herbs and lowest percentages of tropical and temperate trees. The Holocene vegetation is characterized by the expansion of forest with a precipitation maximum recorded between 11 and 8 ka by the highest development of moist tropical deciduous and evergreen trees. In addition, pollen data will be compared with others records of the studied cores, including geochemical vegetation record consisting in the $d^{13}C_{\text{orga bulk.}}$, as well as monsoon indicators estimated on the calculated $dD_{\text{precipitation}}$ based on C28 Fatty Acid and $\delta^{18}O$ of planktonic foraminifers. Therefore, we attempt to better constrain the relationship between vegetation changes, tropical precipitation and weathering in the G-B basin since the last glacial maximum.

Reconstruction of the Indian Summer Monsoon variability and the impacts of Toba super-eruption

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The Toba volcano super-eruption occurred about 74,000 years ago on the island of Sumatra, during the transition between interglacial Marine Isotope Stage (MIS) 5 and glacial MIS 4. This eruption, is currently described as the largest volcanic eruption of the Quaternary. However, its impact on climate is widely debated and its effects on the ocean remain poorly understood. This eruption occurred in an area of the world where important climatic phenomena like the Indian Summer Monsoon (ISM) occur.

The aim of this work is first to reconstruct the variability of the ISM for the last 100 ka. To do so, we reconstructed ocean surface temperature using Mg/Ca of surface-dwelling planktonic foraminifera *Globigerinoides ruber* picked from core BAR94-25 located in the Andaman Sea. We also measured $\delta^{18}O$ on the same samples. By coupling the temperature reconstructed from Mg/Ca and the $\delta^{18}O$, we derived the $\delta^{18}O$ of the sea water ($\delta^{18}O_{sw}$), a proxy of ocean salinity. Andaman Sea salinity is mainly driven by the freshwater discharge of the Irrawaddy River during the ISM. Therefore, $\delta^{18}O_{sw}$ changes in core BAR94-25 are directly related to changes in the strength of ISM since the last interglacial.

After reconstructing the variability over the last 100 ka, we zoomed in on the Toba interval, to decipher the potential impact of the Toba eruption on the ISM. This eruption is characterized in core BAR9425 by several tephra and cryptotephra layers which were interpreted as distinct eruptive events. The results show an increase of sea surface salinity during the Toba eruptive activity, which may be linked to a decrease of fresh water inflow to the Andaman Sea during the ISM. This could reflect the Toba eruption may have disrupted the ocean-atmosphere dynamics and therefore, the ISM.

East Asian winter monsoon variability over the last 700 ka: grain-size evidence from the sediments in the East Sea (Japan Sea)

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This study reconstructed East Asian winter monsoon variability over the last 700 ka based on grain- size distributions of detrital components of the IODP Site U1430 core sediments in the East/Japan Sea. End-member analysis of the grain-size distributions revealed two end-member size distributions, relatively fine-grained EM1 (median size 2.86 mm) and coarse-grained EM2 (median size 9.00 mm), which were interpreted to represent dusts transported by high-level westerlies and East Asian winter monsoon surface winds from the Asian interior, respectively. The relative contributions of EM2 over EM1 in the total size distributions tend to increase in the glacial periods, which are consistent with the grain-size changes in the Chinese Loess Plateau, which tend to be coarse-grained during the glacial periods and fine-grained during the interglacial periods. The changes in the contributions of EM2 suggest that the strengthening of East Asian winter monsoon during the glacial periods has persisted since 700 ka. In addition to the orbital scale glacial-interglacial changes, the contributions of EM2 show sub-orbital millennial-scale fluctuations which tend to be increasing in the relatively bright-colored sediments and decreasing in the dark-colored sediments. The association of EM2 contributions with the sediment brightness change is interpreted to represent the millennial-scale strengthening of East Asian winter monsoon which would have increased the flux of detrital quartz and feldspar and simultaneous facilitated the deep ocean circulation by winter cooling in the East/Japan Sea. Spectral analysis of the millennial-scale cycle indicates that the dominant period is about 6.2 kyrs.

Late Miocene–Pleistocene tectonic and climatic evolution of the Dali Basin, southeastern margin of the Tibetan Plateau: Constraints from the terrestrial sedimentological record

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The southeastern margin of the Tibetan Plateau is a key area for determining whether the late Miocene–Pleistocene environmental changes in the South Asian monsoon region were induced mainly by tectonic activity, climate change, or both. Here we present clay mineralogical, geochemical, and palynological proxies from the terrestrial Dasongping section (7.6–1.8 Ma) in the Dali Basin, which is located in the northeastern Diancang Shan (DCS), SE Tibetan Plateau. Diachronous climatic changes are found in the multiple proxies, with the most pronounced changes occurring at ~4.2 Ma for geochemical and mineralogical indices and at ~2.6 Ma for palynological record. The dominant vegetation changed from subtropical broadleaf evergreen forest to cool-temperate mixed forest or cold evergreen conifer forest. These changes indicate that the climatic conditions of the Dali Basin were warm and humid at ~7.6–4.2 Ma, cooler and humid at ~4.2–2.7 Ma, and cold and humid at ~2.7–1.8 Ma. Various proxies imply that the DCS underwent multiple phases of rapid exhumation during the late Cenozoic. The DCS attained a paleo-elevation of >3500 m above sea level (asl) at ~7.6 Ma, maintained a constant elevation between ~7.6 and 4.2 Ma, underwent multiple phases of surface uplift at ~4.2–1.8 Ma, and reached a paleo-elevation of at least ~4000 m asl during the early Pleistocene. A comprehensive comparison between marine and continental records demonstrates that the climatic conditions of the Dali Basin were controlled mainly by global climatic changes at ~7.6–4.2 Ma and mainly by surface uplift of the DCS at ~4.2–2.7 Ma. Changes in vegetation during the Pliocene were caused predominantly by the increasing paleo-elevation of the DCS, whereas ongoing global cooling with the development of northern hemisphere glaciation played a key role in maintaining cold and humid climatic conditions in the Dali Basin after ~2.7 Ma. Our study discriminates the relative contributions of global climate and regional tectonics on the late Cenozoic environmental changes in the Dali Basin.

Monsoon-driven vegetation changes during glacial MIS 16 in the core monsoon zone of India

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The Indian Summer Monsoon (ISM) is responsible for 80-90% of the annual precipitation in Central India yet understanding the ISM natural variability during past glacial periods remains a challenge in paleoclimate research. The ISM dynamics during the Last Glacial Maximum (LGM) are fairly well-documented but the fundamental drivers of India's hydroclimate are still highly debatable. While boreal summer insolation and the North Atlantic circulation have been commonly considered as the primary forcings at orbital and millennial timescales, respectively, other studies point to the influence of mechanisms related to ice sheet volume, atmospheric CO_2 concentrations and the export of latent heat from the Southern Hemisphere. Paleorecords from glacials prior to the LGM are, therefore, needed to disentangle the forcings driving ISM changes and to evaluate the responses of fragile ecosystems dependent on monsoon rainfall, such as the forests and savannas of India. Here, we focus on the glacial MIS 16 (676-621 ka) which represents one of the most severe glacial periods of the Quaternary, occurring right after the end of the middle Pleistocene transition. Moreover, it is known to be marked by the first instabilities of the Laurentide ice sheet that resulted in the development of Heinrich layers in the northern North Atlantic. We present the first MIS 16 vegetation reconstruction from India's Core Monsoon Zone (CMZ) based on pollen analysis from IODP Site U1446 strategically recovered at the exit of the Mahanadi River to capture a robust signal of the ISM rainfall. Our pollen analysis results will be compared with records from the same site and other proxy and modelling data to unravel the drivers of the ISM dynamics during the cold MIS 16 in the CMZ of India.

Anomalous widespread arid events in Asia over the past 550,000 years

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Records of element ratios obtained from the Maldives Inner Sea sediments provide a detailed view on how the Indian Monsoon System has varied at high-resolution time scales. Here, we present new records from IODP Site U1471 based on a refined chronology through the past 550,000 years. The record's high resolution and a proper approach to set the chronology allowed us to reconstruct changes in the Indian Monsoon System on a scale of anomalies and to verify their relationships with established records from the East Asian Monsoon System. On the basis of Fe/sum and Fe/Si records, it can be demonstrated that the Asia continental aridity tracks sea-level changes, while the intensity of winter monsoon winds responds to changes in Northern hemisphere summer insolation. Furthermore, the anomalies of continental aridity and intensity of winter monsoon winds at millennial-scale events exhibits power in the precession band, nearly in anti-phase with Northern hemisphere summer insolation. These observations indicate that the insolation drove the anomalies in the Indian Summer Monsoon. The good correspondence between our record and the East Asian monsoon anomaly records suggests the occurrence of anomalous widespread arid events in Asia.

Late Pliocene-Early Pleistocene monsoonal climate dynamics recorded in lacustrine-fluvial deposits in Datong Basin, Northern China

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The East Asian summer monsoon (EASM) has responded to the profound global changes with the Northern Hemisphere Glaciation (NHG) since the late Pliocene. The Chinese loess provided generous evidence of the EASM evolution history on tectonic and orbital timescales, while the evidence from lacustrine-fluvial deposits, sensitive to hydrological changes, has remained rare. Here we provide a sedimentary record of lacustrine-fluvial deposits through late Pliocene to the early Pleistocene from the Datong Basin in the northern EAM region, providing independent evidence of the EASM revolution.

The depocenter site experienced through an offshore lake during 3.6-2.7 Ma, alternative lacustrine and alluvial plain during 2.7-1.8 Ma to alluvial plain after 1.8 Ma, mainly reflecting hydrological variations in the basin. Grain size analysis were conducted with the End-Member decomposition. The (EM1+EM2)% (mode size of 4.2 and 10.8μm) was employed as the indicator of low-energy suspended load during the offshore stage and a background hydrology originate from intervals between unsteady upper flow regimes during the alluvial stage, and thus reverse to the hydrological energy. Considering its general negative correlation with color reflectance a* and κfd on orbital time scale during the alluvial stage, the finer fraction (EM1+EM2)% could thus be used as a proxy of EASM precipitation variations.

On orbital time scale, spectral analysis and ensemble empirical mode decomposition (EEMD) of the (EM1+EM2)% reveal the highest variance of obliquity component during the late Pliocene with subordinate precession and eccentricity-like components. During the early Pleistocene, the eccentricity-like component significantly increased compared with that in late Pliocene. This features are identical to records from the Chinese Loess Plateau, while distinct to enhanced and dominant obliquity cycle in global ice volume recorded in LR04. We propose EASM variations on the glacial-interglacial cycles enhanced significantly responded to the NHG across ~2.7 Ma, which disturbed potential meridional insolation gradient forcing of ~40 ka in the late Pliocene. In addition, the enhanced eccentricity-like cyclicity during 2.7-1.8 Ma compared with 3.6-2.7 Ma and even 1.8-1.2 Ma demonstrated that the ice volume explanation of ~100 ka periodicity during mid Pleistocene could not be directly extended to early Pleistocene and before.

Simulated Air-Ocean interaction in the western North Pacific since the Last Glacial Maximum

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1. The Kuroshio Current affects the modern sea level and brings warm and salty water to the marginal seas of the midlatitude East Asia. Since the Last Glacial Maximum (LGM), while the proxy data suggest the subarctic control in the Kuroshio Extension (KE) region during cold intervals, it is not yet clear what specific role played by air-ocean interaction in the vicinity of the western boundary current most efficiently caused such distinction from the present condition.
2. Here, we examine the simulated air-ocean coupled variability in the Kuroshio and the Extension region during the LGM and the mid-Holocene using Paleo Model Inter-comparison Project 4 data archives.
3. Especially, the variability in the meridional location and axis orientation of the north hemispheric Westerly jet associated with the paleo-Arctic Oscillation under such contrasting mean states across the multi model simulations. In addition, for selected models with high enough temporal resolution outputs, storm track activity is analyzed for the two different climate periods in comparison with the present.
4. Finally, the mean and the variability of the simulated Kuroshio with different models are assessed for the contrast under both the LGM and the mid-Holocene climates.

Drivers of Indian vegetation and summer monsoon dynamics during MIS 11

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Asian monsoon variations dramatically affect nearly half of the world's population as the ecosystems, agriculture and economy in Asia are intrinsically linked to monsoon rainfall. The Indian Summer Monsoon (ISM) is the dominant Asian summer monsoon subsystem concerning energy flux, being considered as one of the strongest hydrological regimes on Earth. It brings up to 90% of the annual rainfall into the Indian Core Monsoon Zone (CMZ), where the ISM has its most representative expression. Alarmingly, the uncertainty in ISM precipitation projections is still high due to the complexity of simulating its various interconnections. High-fidelity ISM proxy records of past interglacials, warm periods of reduced ice volume as the Holocene, are thus critical to address important questions regarding the role of the primary forcings (insolation, ice volume and CO_2) in driving ISM natural variability.

Based on pollen analysis at IODP Site U1446 strategically retrieved from the CMZ, this study focuses on the Indian monsoon-induced vegetation changes during MIS 11 (425-374 ka), a key analogue of the current interglacial owing to its similar astronomical configurations, higher than present-day sea-level and greenhouse gas-driven climate warming. On orbital timescales, our results show a first major forest phase during the peak of MIS 11 (MIS 11c) followed by two forest phases separated by open vegetation periods (MIS 11b-a) indicating a shift to drier conditions due to reduced ISM. The forest maximum development occurs during the highest insolation level of MIS 11c which reveals the dominant influence of this forcing on the ISM hydroclimate under interglacial conditions, i.e., relatively high sea-level and atmospheric CO_2 concentrations. However, the forest declines during MIS 11b-a while insolation remains high suggest that the insolation forcing is overshadowed by the influence of increasingly large ice caps and lower atmospheric CO_2 concentrations, as well as the interaction of orbital and millennial scale variability. Our results highlight, therefore, the complex interplay between the forcings in driving hydroclimate and vegetation change under the distinct boundary conditions of MIS 11.

Mass contributions to the early onset of post-industrial sea-level rise from ice sheets and glaciers using sea-level constraints and fingerprinting

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Quantifying historical contributions to sea level from glaciers and ice sheets can elucidate potential impacts of ice dynamics and ice loss in a warming world. This is vital for assessing the (in)stability of ice sheets and glaciers. However, observational estimates of mass loss from Greenland and Antarctica are scarce before the satellite era (*i.e.* prior to the 1990s), and glacier length records before the early 20th century are also sparse. As an alternative to direct observational methods, we can estimate historical ice-mass changes using numerical modelling by calculating past melt and accumulation rates from ice cores, or by undertaking analysis known as sea-level fingerprinting. Sea-level fingerprinting is based on the principle that when an ice mass melts, the contribution to sea level is not uniform around the globe; rather, a spatial gradient in sea-level change can be identified. To use sea-level fingerprinting over historical timescales, tide-gauge data can be employed. However, little long-term data are available for the Southern Hemisphere prior to ~1900. Therefore, tide-gauge data can be supplemented with high-resolution proxy reconstructions (which use microfossils preserved within sediment cores or coral microatolls as sea-level indicators). To assess the source of significant ice-loss contributions over the 20th century, we first select long-term tide gauge and proxy data (*i.e.*, 100 years+). We then isolate the barystatic component in the records by correcting for sterodynamics and the inverse barometer effect. We use an empirically-constrained optimisation model to identify the combination of sea-level fingerprints that best match the observational data. We find a significant contribution from the Greenland ice sheet over the 20th century, as well as from glaciers in Alaska, the Russian Arctic, North America and Asia. Furthermore, our results also suggest a significant contribution from the Antarctic ice sheet.

Regional sea-level highstand triggered Holocene ice sheet thinning across coastal Dronning Maud Land, East Antarctica

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The East Antarctic Ice Sheet stores a vast amount of fresh water, which makes it the single largest potential contributor to future sea-level rise. However, the lack of well-constrained geological records of past ice sheet changes impedes model validation, hampers mass balance estimates, and inhibits examination of ice loss mechanisms. Here we identify rapid ice-sheet thinning in coastal Dronning Maud Land from Early to Middle Holocene (9,000-5,000 years ago) using a deglacial chronology based on in situ cosmogenic nuclide surface exposure dates from central Dronning Maud Land, in concert with numerical simulations of regional and continental ice-sheet evolution. Regional sea-level changes reproduced from our refined ice-load history show a highstand at 9,000-8,000 years ago. We propose that sea-level rise and a concomitant influx of warmer Circumpolar Deep Water triggered ice shelf breakup via the marine ice sheet instability mechanism, which led to rapid thinning of upstream coastal ice sheet sectors.

Discussion on early Holocene relative sea-level changes on the central east coast of the Yellow Sea

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Paleo-relative sea level (paleo-RSL) records are lacking in far-filed of the Pacific coast, particularly the Yellow Sea in Northeast Asia. So far, there have been few research data indicating the beginning of the early Holocene transgression using basal peat on the east coast of the Yellow Sea. The early Holocene transgression data based on basal peat excavated from the study area will be of great significance in that it compares the beginning of transgression between the study site and other areas. We compared the early Holocene RSL history on the central east coast of the Yellow Sea with those of Bohai Bay, the northernmost point, and Gunsan Bay, south of the study area. A multi-proxy approach, including lithostratigraphy, biostratigraphy, combined with radiocarbon and OSL dating, facilitated the generation of 28 sea level index points (SLIPs) using 11 borehole samples. Excavation of basal peat of the 10.3 ka in the study area established that the observed RSL of the transgression in the early Holocene was − 14.88 m, which was much shallower than − 27.9 m in Gunsan Bay at 9.8 ka and was similar to − 17.3 m in Bohai Bay at 9.7 ka. The differences between the observed RSL of the study area and other two areas should be discussed in the viewpoints of a combination of global (glacio-eustatic) sea-level changes and regional land movement. Therefore, we attempt to compare the observed and the predicted in the site's GIA model, discuss the differences between the site and the other two, and estimate the causes.

Holocene regional subsidence and relative sea-level rise in the Netherlands, based on interpolated coastal plain water table rise

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In the Netherlands land subsidence is a major societal problem, caused by both shallow soft soil subsidence (alteration of Holocene strata) and deeper natural subsidence. Isolating the different deeper subsidence components, such as glacio-isostatic adjustment (GIA) and tectono-sedimentary basin loading and sinking, in the total subsidence signal is difficult since these processes act on similar spatial scales and cause similar subsidence rates in the Netherlands. Different methods are used to study the contributions of GIA and tectonic basin loading separately. However, the Holocene rates, the patterns and especially the relative importance of the two processes in the coastal plain are poorly known.

Our aim is to use a data-based approach to reconstruct the contribution of GIA and tectono-sedimentary basin loading and sinking to regional subsidence in the Netherlands during the Holocene using coastal plain water level indicators. We apply a 3D KT-kriging interpolation method (Kriging residuals after applying a Trend function) to our dataset of geological paleo-water level index points (e.g. basal peats) in the Dutch coastal plain (576 observations of X,Y,T and Z), inventoried from many sea-level and inland water table reconstruction studies. The interpolation predicts GW-table elevations on a spatio-temporal grid for given locations X,Y (block averaged at 1x1km) for many moments in time, T (200 yr steps from 10 ka to 1 ka). We use observation-filtering techniques and the outcomes of the trend-fitting part of the interpolation to identify subsidence trends in the RSLR observations. We use kriging of the residuals to resolve further sub-regional patterns (tides, hinterland seepage). The main result of the current research is the ability to produce a data-driven break down of subsidence across the full coastal plain. Additionally, the spatial and Holocene-temporal variance are quantified. Results show that in the Middle Holocene (8-4 ka) a southward reducing GIA subsidence pattern is evident. This reduces in the Late Holocene (2-4 ka), where the remnant GIA signal becomes of equal magnitude as the basin subsidence in the northwest of the Dutch coastal plain. Overall the highest subsidence rates are found in the north east of the country.

Production of postglacial sea-level databases in near, intermediate and far field regions. What are the current limitations?

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In recent years, efforts were made to create Relative Sea Level (RSL) databases in order to a better framework to understand the primary mechanisms of RSL change since the Last Glacial Maximum (LGM). These databases, assembled following a standardized methodology, were used to investigate the different sources of meltwater influx, to reconstruct the deglacial history of the major ice sheets and to calibrate the glacio-hydro isostatic models.

I report here the results some recent RSL databases compiled in very different geographic and climatic regions: The Ross Sea in Antarctica, the Western Mediterranean Sea and the Atlantic coast of Africa.

I will outline some of the inherent difficulties, and potential solutions to analyse sea-level data in such different depositional environments. In particular, I will discuss problems related with the definition of standardized indicative meaning and the considerable lack of modern analogs for sea-level indicators such as beach deposits of fixed biological indicators. I will further address complexities related to different the material used to radiocarbon date the sea-level proxies. I will then discuss how the application new statistical approach on these newly compiled sea level datasets allowed to: i) improving our understanding of the deglacial history in west Antarctica, ii) define the millennial variability in the sea-level rising rates along the Mediterranean coast; i) constrain both the timing and the magnitude of the isostatic highstand along the western marging of the African continent.

Finally, I will discuss the implications of these results for the patterns of glacio-isostatic adjustment in these regions with a particular focus on the possible explanations of the misfits observed between GIA models and RSL data.

Relative sea level over the past 4000 years in the western Mediterranean Sea

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Earth's dynamic response to changes in grounded ice loads drove global scale, geographically variable sea-level fluctuations between glacial and interglacial times. This variability is relatively subtle in the Late Holocene, but an accurate record of pre-industrial sea-level is necessary to place the modern rise in global mean sea level (GMSL) in context relative to natural variability. New results from accurately dated phreatic overgrowths on speleothems that form at sea level in the coastal caves of Mallorca preserve a detailed history of Late Holocene sea level that mirrors GMSL. Our data indicate that sea level stabilized at 0.25 ± 0.11 m (95% confidence) below pre-industrial level at ~3.89 ka. After ~700 years of near-stable conditions, a relatively rapid rise (0.54 mm/year; 95% confidence interval between 0.30 and 0.91 mm/year) to pre-industrial level occurred between 3.26 and 2.84 ka; from 2.84 to 0.07 ka, sea level once again remained stable (within ±0.08 m; 95% confidence) at these sites. Given the tectonic stability of the region, the brief sea-level rise at ~3 ka is best explained by an episode of rapid ice mass flux. As an example, the observed rise can be reconciled by melting of the West Antarctic Ice Sheet equivalent to a GMSL increase of 0.22 m. The observed sea-level history since 3.89 ka is reproduced with a 1D model of glacial isostatic adjustment characterized by a relatively weak upper mantle viscosity of ~10^{20} Pa s with negligible change in ice volumes with the exception of the ~3 ka event. The stability of sea level throughout the Late Holocene, during which there was significant natural climate variability, indicates that the observed GMSL rise of ~3 mm/year over the last few decades cannot be explained by natural climate drivers.

Middle-Late Holocene environmental changes from Malawanna, a coastal wetland in Southwestern Sri Lanka

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Radiocarbon dated core at Malawanna was studied through sediment and palynological analysis to reconstruct palaeoenvironment of the coastal wetlands in the Southern Sri Lanka. The palaeoenvironmental changes in coastal wetlands of the study region were caused by changes in sea-level, climate, vegetation, coastal erosion, sedimentation, seawater intrusion and anthropogenic activities during the Mid-Late Holocene. Pollen core data indicate the Early Holocene rapid sea level rise decelerated around 7,600 cal yrs BP developing a brackish water estuarine mangrove forest in the study region. Sea level transgression and regression at six stages occurred between 7,380-1,000 cal yrs BP whereas the period of existence of sea level high stands was longer than that of sea level low stands. The sea level reached its present level at 1,000 cal yrs BP. Typical lowland rainforest pollen proxy indicates the intensifying summer monsoon trend between 7,600-4,500 cal yrs BP, interrupted by the abrupt dry episodes at 7,300 and 5,500 cal yrs BP. The Mid Holocene monsoon weakened until 3,000 cal yrs BP, whereas the most severe dry (arid) climatic condition prevailed between 4,200-3,900 cal yrs BP. The Late Holocene monsoon rains significantly fluctuated, whereas severe monsoon failures occurred between 2,250-1,900; 1,500-1,200 and 500-400 cal yrs BP. Forest cutting, clearance, biomass burning and soil erosion on the coastal plains were associated with cultured lowland rainforest environment between 6,000-4,000 cal yrs BP. Responding to climatic amelioration and sea level low stands, management of the cereal-type plant, e.g., rice cultivation and crops (*Areca* sp. and *Durio* sp.) commenced between 5,600-5,500 cal yrs BP. A climatic shift from humid to severe arid vanished the plant management until 3,600 cal yrs BP. The fluctuation of the Late Holocene monsoon supported the re-establishment of rice cultivation with the appearance of *Cocos* sp. (cf. *nucifera*) in the Southern coastal plains. The rice cultivation was more likely to have increased between 2,250-1,900 and 1,500-1,200 cal yrs BP, whereas the monsoon downturn prevailed.

Holocene relative sea-level database of the mid-Pacific

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Holocene relative sea-level (RSL) records from the mid Pacific are useful for inferring ice-equivalent sea-level changes and for constraining glacial isostatic adjustment (GIA) models. However, reconstructions of RSL from the mid-Pacific are hindered by differences in study methods and by the reworking and/or post-depositional lowering of dated material. Here, we present a standardised, quality-controlled database of published RSL data from five island groups in the mid-Pacific: Cook Islands, Tuamotu Islands, Christmas (Kiritimati) Island, Gilbert Islands and Fiji. We critically assessed the RSL data derived from various sea-level indicators (e.g., peat, beachrock, corals) and developed criteria to classify high and low quality RSL data.

We rejected 152 of the 614 data points and reinterpreted 178 sea-level index points (SLIPs) as limiting data. Of the remaining 59 SLIPs, 240 marine limiting and 163 terrestrial limiting data points, ~90% are < 6 ka and ~70% are high-quality. We show that the early- to mid-Holocene evolution of RSL in the mid-Pacific is not as well understood as previously thought and that there is currently no unique solution for a global ice-melting history due to poor constraints of data. For example, while the Fiji data were formerly used to justify the ice-melting histories of GIA models that predict a highstand at ~4 ka, our database cannot preclude alternative highstand timings between ~2.8 ka and ~6.1 ka. We also illustrate how data-quality consideration can influence the choice of best-fitting GIA models by assigning different weights to low-quality data. This study emphasises the need to standardise and critically evaluate the RSL data that are used for GIA model validation.

Common Era relative sea-level changes in Southeast Asia: A new reconstruction from the Matang Mangrove Reserve, Malaysia

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Reconstructions of past relative sea level (RSL) during the Common Era (last 2000 years) have shown a response to natural climate warming and cooling phases such as the Medieval Climate Anomaly and Little Ice Age. Coupled with long-term instrumental measurements from tide gauges, they also showed a timing of emergence in RSL rate centered around the mid-19th century, with a 20th century rise that is extremely likely ($P \geq 0.999$) faster than the proceeding 3000 years. These conclusions, however, are derived from RSL reconstructions and tide-gauge records that currently excludes Southeast Asia and hinders the interpretation of sea-level change and the validation of models that predict future changes and their spatial variability.

Here, we present a new RSL reconstruction using mangrove sediments from the Matang Mangrove Forest Reserve, western Peninsula Malaysia to constrain RSL change during the Common Era. Stratigraphic investigations of the site revealed uniform sedimentary sequences comprising subtidal and intertidal silty clay muds overlain by organic mangrove peats to depths of ~2.5 m. From this we extracted a type core based on quality of preservation of mangrove peat that was surveyed relative to Malaysian geodetic benchmarks. We constrained temporal uncertainties using accelerator mass spectrometry radiocarbon dating of in-situ plant macrofossils and bulk sediment fine-fractions coupled with short-lived radionuclide chronohorizons within a Bayesian age-depth framework. We constrained vertical uncertainties using a modern training set of biological markers from foraminiferal tests in combination with new approaches to confirm their presence or absence in fossil sediments through environmental DNA analyses.

We applied a spatiotemporal empirical hierarchical model to quantify the magnitude and rate of RSL change. We compared the new reconstruction with a compilation of published RSL data from southern Peninsula Malaysia and Singapore that suggested RSL fell ~1m below present between 2 ka and 0.5 ka years before present. Furthermore, we evaluated glacial isostatic adjustment model predictions with the new reconstruction to assess the influence of driving processes of RSL change.

Salt Marsh Microfossil Sea-Level Reconstruction along the South African Coastline using Bayesian Transfer Functions

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To predict future sea-level rise, recent trends need to be examined to provide context regarding short and long-term variability. Sea-level records in South Africa have been generated by a range of proxies spanning from ~ 250 000 yr BP, however these records are discontinuous and lack the resolution needed to disentangle natural variability from anthropogenic climate forcing. SA's far-field location eliminates isostatic effects associated with recent deglaciation, reflecting eustatic sea-level behaviour, thus making it an ideal location for Late Holocene reconstruction. The performance if regional and site-specific Bayesian transfer functions based on modern microfossil data from multiple estuaries are compared for sea-level reconstruction along the southern coastline of SA. Sediment cores are chronologically constrained using Bayesian age-depth models based on AMS radiocarbon and Pb-210 dating. The results of the sea-level reconstructions show higher than present sea level occurring between ~1100 and ~500 Cal yr BP, falling to ~0.6 m lower than present sea level at ~ 500 cal yr BP, followed by a rise to present sea level. Model performance shows similar coverage for both the regional and site-specific models, with the site-specific scoring the lowest root mean squared error. The regional transfer function observed vs predicted values display more noise associated with variability between sites when compared with the site-specific approach. We explore state of art methods in high-resolution sea-level reconstruction to shed light on the optimum balance in precision and prediction power.

Strategy and problems to set up a global relational database for sea-level data

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The information provided by sea level index points can be classified to be diverse by means of character and accuracy. Recent standardized compilation strategies for sea level datasets (e.g., HOLSEA or WALIS) result in an increasing number of regional dataset publications.

Glacial isostatic adjustment or paleo-climate modelling demands a global access to such data. Accordingly, datasets have to be combined and unified. Focusing on the HOLSEA compilation, the filling of the respective spread sheets by different groups remains inconsistent beside its detailed documentation (https://www.holsea.org). In most cases, the meaning of specific fields is interpreted differently. One has to keep in mind, the HOLSEA format contains about 80 fields. This impedes to string together the respective datasets directly in order to form a global dataset. Furthermore, research evolves and, so, the number of fields will rise, interpretation of specific information will change and values of specific fields have to be updated regularly.

The HOLSEA compilation covering the last 20,000 years contains already about 6,000 data points, demanding an automatized access as well as update of the data. In order to evaluate this compilation, we have setup a server-based relational database RSL2, in which we first store all datasets in their original form separately and then adapt or combine deviating formats by implementing specific rules or functions. This strategy keeps the process transparently and also allows to update the data routinely, when additional information is provided or the interpretation of specific fields has to be adjusted. Furthermore, we have defined interfaces for recalibration of radiocarbon ages with the most recent IntCal20 calibration curve and for uniform tidal corrections applying the global (palaeo-)tidal model TiME.

In sketching the respective compilation steps, this presentation can be seen as a lessons-learned tour, while setting up this database structure. But most important, the SQL-format allows direct access by analysis and visualization tools, provided that suitable interfaces are programmed. As an example, we could identify a potential late-glacial lake stage of the White Sea, while analyzing indicative ranges due to variations in tidal levels over time.

Reconstructing recent relative sea-level variations using saltmarsh foraminifera in the North Atlantic

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Sea level rise (SLR) varies in time and space in response to a suite of different controlling mechanisms. Modern-day instrumental measurements of sea level are too short to reliably establish secular rates of SLR and unravel the relative contributions of the processes driving sea level change. The reliable reconstruction of past relative sea-level (RSL), using foraminifera buried in high-saltmarsh sediments, allows us to extend the historic sea level record. This methodology, known as the ‘geological tide gauge technique’ (GTG), allows the development of near continuous high-resolution records of RSL change and a better understanding of the processes driving RSL variations, both in time and space. Due to the spatial bias of recent RSL reconstructions, there remains considerable uncertainty regarding the contribution from regional and local scale processes to spatial and temporal RSL variability, outside of the western Atlantic margin (Kemp et al., 2018). In this study, we apply the saltmarsh based GTG approach in Ireland and Canada, with the aim of reducing the spatial and temporal gap in recent RSL reconstructions. We present new regional training sets of contemporary saltmarsh foraminifera, to quantify the relationship between elevation and foraminiferal assemblage and produce a predictive transfer function for each study area. Individual high resolution RSL reconstructions have been developed for Ireland and Canada by the application of the GTG technique. We finally compare the RSL reconstructions to assess the spatio-temporal evolution of RSL in the North Atlantic and test the relative importance of local, regional and global processes for determining spatial trends.

Historic Relative Sea-Level Rise in South Carolina, USA: How to Get a Grip on Local Subsidence and the Implications for Future Flood Risk

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Along the east coast of the United states, rates of relative sea-level rise vary greatly due to differences in ocean dynamics and local to regional subsidence. Within the southeastern region, there is a gap in accurate and modern data points related to relative sea-level rise between southern North Carolina and Charleston, South Carolina. In this region, lies Myrtle Beach, South Carolina, one of the fastest growing cities in the country and a hot-spot of tourism. The modern rate of relative sea-level rise in this area is significantly faster over the last century (4.6 ± 0.6 mm/yr) compared to Charleston (3.3 mm/yr; 100 km to the south) and Wilmington (2.5 mm/yr; 185 km to the north) due to a current undifferentiated subsidence effect of 2.9 mm/yr in the Winyah region (the region's major estuary). Nuisance and compound flooding have become a common occurrence in the area over the past years. Myrtle Beach experienced 72 hours of nuisance flooding per year in 2001-2015 with a projection of 1,368 hours per year by 2045 (Dahl et al., 2017); Data collected from Georgetown, a low-lying historic city on Winyah Bay, indicated 436 hours of flooding in 2021 with a projection of a majority of the year having daily flooding events by 2040.

The demand is urgent for qualitatively and quantitatively understanding the natural and anthropogenic mechanisms that lead to rising coastal water levels. The three goals of this study are to a) Resolve historic sea-level changes (recent centuries) at inter-decadal resolution; b) Quantify local short-term (decades) and long-term (millennia) subsidence rates (land sinking) by distinguishing the various participating natural and anthropogenic processes; c) Informing and assisting local communities in assessing their current and future flood risk. The study will be conducted using a combination of geodetic, historic, geological, and on-site monitoring approaches. These data will be integrated into a regional framework to examine temporal and spatial variations.

High-Resolution Late Holocene Relative Sea-Level Reconstruction in the Northeastern Gulf of Mexico and Implications to Regional Variability

Mr. Zachary Czoer [1], ***Dr. Zhixiong Shen*** [1], ***Prof. Mead Allison*** [2], ***Prof. Barbara Mauz*** [3]

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High-resolution stratigraphic studies are important for exploring the spatial and temporal variability of relative sea level (RSL) at centennial to millennial timescales. These studies are rare in the northern Gulf of Mexico (NGOM), where the relative effects of glacial isostatic adjustment (GIA) and sediment isostatic adjustment (SIA) in the Mississippi Delta, and climate change have been debated. This study adds a 3000 yr basal-peat-based RSL reconstruction at St. Vincent Island (SVI), a barrier island in the northeastern GOM where we found around 1.5 m of salt-marsh peat overlaying barrier sand. The above-modern sea-level beach ridges in SVI were used to argue for Holocene RSL high stand in the region. The bases of the peat deposits were surveyed for elevation control through differential leveling and DGPS measurements and dated using ^{14}C and optically stimulated luminescence to create sea-level index points. The new RSL data was also analyzed along with data from published NGOM studies using a spatial-temporal empirical hierarchical model. Preliminary results show that the RSL in our study area increased by around 1.5 m over approximately 3000 yr at an average rate of 0.5 mm/yr. The rate agrees with other regional studies, including those from the Mississippi Delta, confirming that the late Holocene RSL rise in the NGOM is dominated by GIA and that the effect of SIA in the Mississippi Delta is small. Our results also confirm that the beach ridges of SVI and similar high beach ridges in other NGOM sites are not accurate sea-level indicators. Initial results from the hierarchical model show that the regional component of RSL fell from -1000 to 1000 CE, coincident with the southward shift of the ITCZ, suggesting a likely climatic forcing of the RSL signal. Additional data and statistical analysis will be presented in the meeting.

Late-glacial to Holocene relative shore-level data covering the Baltic Sea

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The glacial history of the Baltic region is of interest for paleo-climate reconstructions and the sea-level change of this region and its surrounding. One major aspect is the repeated opening and closing of the Baltic Sea since the last glacial maximum. During the different lake stages (Baltic Ice Lake and Ancylus Lake) following the last glacial maximum, the Baltic basin filled up with meltwater of the retreating Fennoscandian ice sheet and so deviated significantly from the global ocean's sea level. Furthermore, variations in relative shore-level height around the respective lake's stage were controlled by the glacial isostatic adjustment of Fennoscandia. The water itself has been transported away continuously through channels or was rapidly drained during catastrophic events, releasing large amounts of freshwater into the oceans. Baltic Ice Lake drained a large amount of fresh water at least twice, lowering the water levels in the Baltic Sea Basin by up to 20 m and 25 m, around 12.9 cal ka BP and 11.7 cal ka BP, respectively. The magnitude of Ancylus Lake up-damming around 10.8-10.0 cal ka BP varies from 20 to 10 m depending on the intensity of the uplift. Submerged rooted pine stumps from Hanö Bay in the southern Baltic at different elevations suggest a rapid lake level rise of ~40 mm/year of the Ancylus Lake. The reconstruction of the lake levels and their dynamics have to be based on RSL indicators for which a respective database has to be built up. Accordingly, we will extend our recently published database of Holocene data covering the Baltic Sea, which already contains a larger amount of shore-level data covering the Ancylus Lake phase. Also, for this compilation, we follow our preferred strategy and store the already published data in an SQL database system in the format given in the original publication. Homogenization, formatting, and additional information will be given by specific rules and will end up in a HOLSEA-consistent format. The results of this compilation will contribute to the PALSEA efforts on sea-level data as well as to the German paleo-climate modeling initiative PalMod.

Dynamics and drivers of fen-bog transitions in northern peatlands

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During their development, peatlands commonly transition from wet, nutrient-rich, biodiverse, methane-emitting fens; to drier, nutrient-poor, carbon dioxide-emitting bogs. These changes in wetness and trophic status reflect decreasing hydrological connection between a peatland and local sources of mineral-rich surface-water and shallow groundwater. Such hydro-chemical changes also cause pronounced shifts in plant assemblage along a semi-predictable successional gradient, and are thus identifiable in plant macrofossil records from peat cores. The drivers of fen-bog transitions (FBTs) remain a subject of ongoing research. Spatial patterns in the contemporary distribution of northern fens and bogs have been taken to suggest that climate plays a role in driving FBTs, but other factors such as landscape age and topographic wetness may also be important. We present a two-part analysis that seeks to establish spatiotemporal patterns of FBTs in northern peatlands since the Last Glacial Maximum, and to elucidate the drivers of these trophic changes. Firstly, a reanalysis of more than 100 published plant macrofossil records indicates that the most rapid phase of FBTs in northern peatlands occurred during the late Holocene, between approximately 5 and 2 ka BP. Long-term apparent rates of peat accumulation vary greatly between study sites, but are remarkably consistent between fen and bog phases within sites. We take this to indicate the important role of site-specific hydrotopographic setting in controlling peat accumulation and FBT timing. Secondly, a geospatial analysis reveals that the contemporary distribution of fens and bogs in Canada is related to time since deglaciation and/or drainage of postglacial waters. Bogs are more common in older landscapes in which peat has had longer to accumulate, lifting the growing surface above external hydrological influences, whereas fens are more common in younger landscapes, particularly along the shores of the Hudson and James Bays. Topographic wetness is also important, with fens being more prevalent in poorly drained, down-flow locations. Peatland trophic status is less clearly related to climate, meaning that fen and bog distributions may resist a poleward shift despite ongoing warming.

The long-term development of peatlands in western Amazonian

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Most of the currently known intact peatlands for the Amazon Basin are in the western Amazonian region, an area that receives the largest annual precipitation in the basin. These peatlands sequester large amounts of carbon and therefore play an important role in the global carbon cycle. This significant carbon sink region may switch to a major source of greenhouse gas emissions through land-use changes and more frequent drought events associated with anthropogenic climate change. Therefore, improving understanding of the mechanism of peatland development in western Amazonia is becoming increasingly important. The purpose of this project is to use multiple sediment cores from Colombia and Peru to better understand the long-term development of peatlands in western Amazonia during the Holocene, as well as examine how key ecosystem functions such as carbon accumulation have changed over this period. Peatlands are important archives of past environmental change, with ongoing analysis of organic carbon content, palynomorphs, and pyrogenic carbon providing insight into Holocene carbon accumulation rates and vegetation dynamics for this region, as well as the impacts of fire and how peatland development varied spatially within the western Amazonian region. Preliminary results showed that peatlands disconnected from the river channel exhibited smaller variations over time in carbon content and bulk density compared with those under the influence of fluvial activities. Further results are expected to contribute knowledge about current ecosystem resilience and peatland dynamics that will assist with the development of future management of the western Amazonian peatlands

Holocene hydroclimatic and fire dynamics on the southern Cape coast of South Africa - A 7.2 ka multi-biomarker record from the peatland Vankervelsvlei

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Fire is a natural phenomenon along South Africa's southern Cape coast during the Holocene, but identifying its climatic drivers has been subject of considerable debate. In this study we investigate hydroclimatic and fire dynamics on a 9.6 m long sediment core from Vankervelsvlei covering the past 7.2 ka. The fen is located near the southern Cape coast at an elevation of 152 m above mean sea level within the year□round rainfall zone of South Africa. For reconstructing hydroclimatic dynamics, we analysed oxygen isotopes from hemicellulose-derived sugars and hydrogen isotopes from leaf wax-derived *n*-alkanes. Coupling both isotopes enables to robustly reconstruct the atmospheric source and seasonality of precipitation as well as local relative humidity. Past trends in fire activity are inferred from macro-charcoal and innovative polycyclic aromatic hydrocarbon (PAH) analyses, the latter serving as fire biomarkers in our study.

Results indicate high fire activity at Vankervelsvlei accompanied by generally moist conditions and a year-round rainfall regime due to contributions of both Westerly-derived winter precipitation and Easterly- and locally-derived summer precipitation from 7.2 to 4.0 ka cal BP. From 4.0 to 2.0 ka cal BP, low fire activity is accompanied by rather dry conditions due to the presence of Westerly-derived winter precipitation but a decrease of Easterly- and locally-derived summer precipitation leading to a shift to a winter rainfall regime. From 2.0 ka cal BP until present day, macro-charcoal and PAH concentrations show diverging patterns, possibly due to the impact of anthropogenic activity, e.g., wildfire control and man-made fires for food production. This period shows variable climatic conditions but moisture is generally increasing due to increasing contributions of both Westerly-derived winter precipitation and Easterly- and locally-derived summer precipitation leading to the presence of a year-round rainfall regime along the southern Cape coast.

Our study highlights that the frequency of El Niño Southern Oscillation is a potential driver of short-term hydroclimatic dynamics, which drives fuel availability and fire activity at Vankervelsvlei during the Holocene. Results from Vankervelsvlei are in line with regional records providing a coherent hydroclimatic and fire picture along South Africa's southern Cape coast.

Recent carbon sink capacity of subtropical peatlands in China

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Atmospheric CO_2 concentration has increased substantially and rapidly since the industrial revolution, resulting in global warming. Mitigating global warming and achieving carbon neutrality is therefore a topical issue for many communities. Peatlands are globally important carbon stocks, and have the great potential of either cooling or warming the climate. However, compared to high-latitude peatlands, the low-latitude peatlands have received little attention and are currently poorly understood. In this study, we investigated and sampled different subtropical peatlands along an 1800 km transect in southern China. We found very diverse conditions of subtropical peatlands, e.g., newly appearance of *Sphagnum* patches at one site and increasing bamboo dominance due to drying at another site. We are currently studying the recent changes in peat carbon accumulation over the past *ca.* 300 years using multiple dating approaches and peat property analysis. We will also measure modern carbon fluxes in these peatlands. Together, our results will provide valuable insights into the recent and also future peatland carbon sink capacity in the subtropics.

Palaeoecological reconstruction of 2000 year-long history of Sphagnum peatland development in the context of the transition from a mixed forest to a pine plantation

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The *Sphagnum*-dominated peatlands are very sensitive not only to global climate change but also to local human activities. Therefore, they are suitable for palaeoecological reconstructions. A particular case of anthropogenic changes that influence peatland functioning is a change in the forest composition related to planned forest management, for example, from mixed forests or open areas to plantations/monocultures. Based on multi-proxy analyses, it is possible to trace the history of the development of peatlands and their nearest surroundings, both locally and extra-locally. In this study, we analyzed a peat core from the Miały peatland, surrounded by a pine (*Pinus sylvestris*) plantation – the Noteć Forest (NE Poland). The main objective is to trace the local history of the peatland's development over the past 2,000 years, with particular emphasis on the period associated with the transition from mixed forests to pine monoculture, focusing on how forest management impacted the vegetation and hydrological conditions of the peatland. In addition, we investigate the response of the peatland to extreme events, including fires and insect outbreaks. Our reconstruction is based on a high-resolution multi-proxy approach, including pollen, plant macrofossils, charcoal and testate amoebae. We also use neodymium isotopes to reconstruct possible inputs of mineral matter associated with human activity in the area. Our results show that the introduction of planned forestry and pine monoculture planting led to substantial changes in the composition of peatland vegetation in favor of mosses. That dramatic change caused significant fluctuations in the depth of the water table in the peatland. We are testing the hypothesis that pine afforestation affects peatland acidity, trophic state and hydrology. The results of the study are essential for forest ecology and forest management in the temperate climate of Central and Eastern Europe. Furthermore, we want to underline the significance and importance of ecosystem services of wetlands for forest ecosystems and sustainable forestry.

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Signature and ecological consequences of abrupt climate change in northeastern China: A multiproxy-based investigation of the Younger Dryas

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During the rapid deglaciation period, temperatures in the Northern Hemisphere suddenly returned to near-glacial conditions (average temperature decrease of about 3°C). This near-glacial period is called the Younger Dryas (12,900 to 11,600 cal. yr BP). Plenty of geological evidence exist around the Atlantic region that recorded this abrupt climate shift. However, the timing and amplitude of the YD and its potential impacts on terrestrial ecosystems are still in great dispute, particularly in East Asia. Current results even point to contrasting 'wet vs. dry' conditions. Information about the hydroclimatic conditions in East Asia during the YD and its impacts on terrestrial ecosystems will improve our understanding of abrupt climate shifts in particular their global impact. Such information, however, is still lacking. This knowledge gap results from the absence of suitable proxies that can reconstruct past hydroclimate parameters quantitatively, and the absence of absolutely dated vegetation records. In this study, we focused on a peatland located in northeastern China and used cutting-edge compound-specific hydrogen isotope analyses to quantitatively reconstruct the hydroclimate conditions during the YD. The reconstructed hydroclimate sequence was compared to the pollen-inferred vegetation history, to evaluate the response of regional vegetation to abrupt climate shifts. In addition, the multiple proxy dataset obtained from the investigated peatland, such as TOC content, $\delta^{13}C$ of bulk organic matters, metal element concentration, and biomarkers, will help generate the influence of abrupt climate change on terrestrial ecosystems. These detailed palaeoenvironmental and palaeovegetation reconstructions at geographically spread study sites combined with reliable correlations between them would be used to shed light on the challenging problems concerning the hydroclimate conditions during the YD and its influences on vegetation succession, and inform models that will be used to predict the response of vegetation dynamics to future climate anomaly in monsoonal Asia.

Centennial-scale habitat change in European high-latitude peatland vegetation towards Sphagnum dominance

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High-latitude peatland vegetation and consequent carbon dynamics are under a change as Arctic areas are warming at least double the rate of the global average. Permafrost thawing is an ongoing process in high-latitude peatlands and changes in peatland hydrology are expected due to both thawing permafrost and increased evapotranspiration. Hydrological conditions are a key for the prevalence and compositions of peatland vegetation that drives carbon dynamics. Both of these are expected to change, leading to uncertainty in future peatland carbon budgets.

We have compiled a comprehensive set of 33 peat records from 16 high-latitude peatlands in Fennoscandia and European Russia and reconstructed the changes in vegetation compositions over time. Our data covers the past two millennia and a special focus is on the recent centuries. Records collected from permafrost mounds (6 records) showed a vegetation change from sedges to dry vegetation reflecting permafrost aggradation. We show a habitat change pattern where intermediate microhabitats of permafrost (17 records) and non-permafrost (4 records) peatlands have undergone a change from wet indicating sedge dominated vegetation to the current Sphagnum moss dominated drier conditions. Sphagnum mosses are connected to higher peat and carbon accumulation rates and thus this habitat change may have a significant effect on carbon sink capacity of high-latitude peatlands, if this process is amplified by climate change.

Postglacial climate and wetness changes in the Linje mire, Poland (Central Europe)

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Palaeoecological methods are a practical approach to understand past climate change impacts on the environment and biota. Peatland archives represent excellent resources for high-resolution paleoclimate studies due to their ombrotrophic nature. Plants and testate amoebae are two proxies of the biota that differ in their response speed to water-table changes. A multi-proxy analysis of vegetation and testate amoebae assemblage dynamics gives a broader understanding of past climate-driven mire surface wetness changes.

Linje mire is a protected peatland located in northern Poland, near the city of Bydgoszcz. The vegetation on Linje mire indicates a poor fen, but areas of ombrotrophic vegetation are present in the centre of the site, from where a 12 m length peat core was extracted. In addition to hosting several experimental research projects, the site is the only remaining *Betula nana* habitat in the Polish lowlands.

The 12 m core recovered from Linje mire has an extensive ^{14}C and tephra chronology, thus providing a palaeoecological record from the Late Glacial until the present. To date, Linje mire is the only site in Poland, where the existence of a stable peat bog is confirmed for such a long time. Testate amoebae analysis has already been performed at 5 cm resolution and has been used to reconstruct palaeohydrological conditions at the site. These results will complement plant macrofossil, pollen, non-pollen palynomorphs, charcoal and microphenological analyses of subfossil dwarf birch leaves. This multi-proxy approach will be used to reconstruct past vegetation and mire surface wetness changes at a local scale and track climate change as well as human impacts on the peatland ecosystem. Moreover, microphenological analysis of subfossil *Betula nana* leaves will provide insight into the spring seasonality changes of the Holocene period.

Expanding boreal peatlands – case studies from Finland

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Under the present climate crisis, it is crucial that all factors contributing to the global carbon cycle are profoundly understood. In this cycle, peatlands play a major role, but their current spatial dynamics – especially regarding the expansion of peatland margins and development of new peat patches – have been overlooked. We studied the lateral expansion of Finnish peatlands over the last decades and centuries by means of radiometric dating of the basal peat of the peatland margins. In addition, mineral substrate and landscape features, including terrain topography and slope, were studied using sedimentological and remote sensing techniques to analyse possible causes and constrains for the lateral expansion.

Our results show that lateral expansion is still occurring all around in Finland. However, the spatiotemporal patterns vary even within the same peatland. Five out of six studied peatlands indicate substantial areal expansion during the last 150 years. On these sites, the peatland margins have expanded from the center of the peatland towards the edges in chronological order. In two other cases, the lateral expansion data were more complex.

In short, our new finds reveal that under current climate conditions new long-term carbon sinks and pools are emerging. Our results further show that the long-held view, according to which all the topographically suitable areas for lateral expansion are already covered by peat, is not valid. The lateral expansion is still an on-going process that is, in addition to carbon cycling, affecting the boreal landscapes and ecology in multiple ways.

Climatic and hydrological controls on peatland accumulation rates

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Peat accumulates when there is a positive mass balance between plant productivity inputs and litter/peat decomposition losses. Here we examine the peat accumulation rates from 28 well-dated European peatlands. Peat accumulation rates range between 0.005 and 0.448 cm yr^{-1} (mean = 0.118 cm yr^{-1}). Our work provides important context for the commonplace assertion (of unknown origin) that peatlands grow vertically at ~1mm yr^{-1}. We find that summer temperature is the strongest control on the site average and highest recorded accumulation rates across our European sites. Peatland accumulation rates tend to also be higher when water-table (reconstructed from testate amoeba subfossils) is within the 5-10 cm range. When a Gaussian response curve is fitted to the data, the optimal water-table depth for greatest peat accumulation is ~10 cm. Peat accumulation rates appear to be generally lower when water table depths are <0 cm (standing water) or >25 cm, which may relate to a decrease in plant productivity and increased decomposition losses, respectively. These findings corroborate previous experimental studies which examined the relationship between peatland water-table depth, or the thickness of the aerobic surface layer (the 'acrotelm'), and the rate of peat formation. Our work suggests that an average water-table depth of around 10 cm is optimal to enable rapid peat growth and therefore carbon sequestration in the long term, which supports current experimental studies and informs targets set in peatland restoration and rewetting projects, as awareness of the peatland carbon stock's vulnerability to climate change continues to grow.

Quantitative analyses of testate amoebae as a potential bioindicator of chromium contamination in peatlands

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The largest peatland complex of Canada and the second largest contiguous wetland in the world, the Hudson Bay Lowlands (HBL), spans the northern regions of Manitoba, Ontario and Québec. Large chromite deposits are situated in this highly sensitive environment, which are targeted for mining of critical metals, i.e., chromium. Chromium (Cr) is a common environmental contaminant, predominantly found in aquatic ecosystems as Cr(III) and Cr(VI). Cr(III) is more abundant and is largely immobile precipitated or adsorbed onto mineral, although it can be mobilized by forming complexes with dissolved organic carbon. Conversely, the genotoxic carcinogenic Cr(VI) is mobile in natural waters where reducing materials are limited and can occur as a result of erosion/weathering of chromium deposits or, more commonly, from industrial pollution. The potential fate and impact of Cr in the HBL is currently unknown.

Using pre-mining site in northern Quebec, Ménarik Lake, this study aims to assess natural Cr background and its fate in a typical northern boreal environment. The mobility of Cr due to natural weathering, changes to water table depth, changes in lake sediment redox transition zone, and forest fires will be evaluated using peat natural archives. In particular, testate amoebae, a biological indicator sensitive to climatic and ecological change, will be investigated alongside a comparison of metalloid profiles. Testate amoebae have been extensively used to reconstruct water table depth and have also been shown to be a viable bioindicator for certain metalloid contamination.

The main objectives of this study are to: 1) quantify testate amoebae assemblages in the pre-mining site, 2) develop a transfer function to reconstruct water table depth, 3) determine if testate amoebae can be used as a bioindicator for Cr contamination through multivariate and ordination techniques in conjunction with metalloid concentration data. This will improve our understanding of how the mobility of metals and metalloids are affected in wetlands as they respond to changes in climate and anthropogenic stresses.

Long-term changes in Carbon accumulation in mountain peatbogs in the South-West of Norway

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There is relevant research on temporal carbon accumulation changes, mostly in arctic permafrost peatlands in Norway, but little is known about the differences and comparisons with more oceanic and lower latitude peatlands in the region, where rainfall is one of the main climatic drivers. Climate projections in Norway for 2031-2060 and 2071-2100 show a rise in mean temperature and an increase of annual rainfall with more intense seasonal events in western, eastern, and northern parts. Under this rationale, this study hypothesizes that temporal variability of temperature and precipitation during the Holocene led to weaker and stronger evapotranspiration and moisture signals affecting local and regional vegetation in peatland ecosystems, water-table changes, and carbon accumulation capacity. This study will contribute to the generation of evidence of the roles and interactions of hydrology, temperature, vegetation, and land use changes on peatbogs carbon accumulation capacity during the Holocene. It will help to disentangle the responses of the carbon budget at different time scales. Methods involve the use of a set of proxies such as pollen, testate amoeba, LOI and bulk density to reconstruct the peat composition rate, organic matter, water table, and local (and regional) vegetation. A generation of an age-depth model and further multivariate analysis will allow to investigate the relationship between the proxies and carbon accumulation rate over the Holocene to further understand the temperature/precipitation correlation and the effects of a changing climate on the carbon budget.

Keeping above the waves? The response of coastal freshwater peatlands to sea-level rise

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Global mean sea-level rise is occurring at an increasing rate, and is projected to continue under all future emissions scenarios. With high emissions, we cannot rule out a rise of 15 m at 2300 (IPCC AR6, 2021). Understanding coastal responses to sea-level rise is a priority for policymakers and land managers, especially as the influence of coastal processes is likely to extend further inland with rising seas. Much previous work has addressed the impacts of sea-level rise on saltwater wetland ecosystems, such as saltmarshes and mangroves, but less attention has been given to freshwater systems such as peatlands which occupy equally vulnerable spaces.

Peatlands are significant ecosystem service providers: they store at least twice as much carbon as forests, attenuate floods, improve water quality, and enhance biodiversity (Loisel *et al.*, 2020). Will rising seas threaten the survival of these systems? Or will they adapt to or keep pace with this environmental change?

This PhD project takes a past-present-future approach, combining peatland palaeoecology, contemporary ecohydrological monitoring and future-facing sea-level projection modelling approaches. Here I present Holocene-age multi-proxy palaeoecological reconstructions (testate amoebae, diatoms, LOI) used to investigate what past sea-level rise has meant for peatland function at two key UK sites: Cors Fochno, a raised bog on the Welsh coast, and Wheatfen, a floodplain fen in Norfolk.

Record of the Late Glacial-Holocene palaeoenvironmental changes in landslide fens deposits of the Polish Carpathians

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Depressions occurring in landslides initially tend to fill up with water, and subsequently with organic deposits, transforming in that way into landslide fens. The delivery of allochthonous material to these fens during intense rainfalls (generated slopewash processes) causes the peat to be intercalated with horizons of mineral sediments. Multiproxy analyzes of landslide fen deposits based on lithological, palynological and non-pollen palynomorphs (NPPs) analyzes, as well as Cladocera, diatoms, geochemical, and dendrochronological studies of subfossil wood, allow for the reconstruction of palaeoenvironmental changes in the Carpathians during the Late Glacial and Holocene. In the Polish Carpathians, several dozen of landslide fens have been analyzed in detail. The horizons of mineral sediments in peat sequences indicate a particularly strong increase in climate humidity in the Bølling and Allerød interphases of the Late Glacial, at the beginning of Preboreal, at the end of the Boreal Phase and the beginning of the Atlantic Phase, at the transition Atlantic/Subboreal phases, in the middle Subboreal, at the beginning of the Subatlantic phase and during the Little Ice Age.

In the upper parts of these fens, mineral covers (0.5-2.0 m thick) have formed. The beginning of their formation was related to the climate moistening during Subboreal and Subatlantic phases. In several fens, sedimentation of mineral covers is continued today, when short-term flooding of peatlands with water during intense rainfall occurs. In two landslide fens, the fluctuation of the water table are monitored instrumentally. The increase in thickness of mineral sediments deposited during single events causing flooding of the fen is highly variable and ranges from a fraction of a half millimeter to 4 cm.

The dendrochronological analysis of a dozen subfossil trunks of fir (*Abies alba*) exhumed from the sediments of the Kaletowa landslide fen in the Beskid Makowski Mts. allowed for the development of a short floating chronology of fir. These results emphasize the high research potential of fens that are sensitive indicators of palaeoenvironmental changes in the Late Glacial and Holocene in the Carpathians.

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Multi-Proxy Investigation of the Relationship between a Drying Climate, Peatlands and Human Activity

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As atmospheric CO_2 concentrations continue to increase and contribute to global warming, peatlands are increasingly susceptible to drier conditions. Ombrotrophic peatlands are especially vulnerable to climatic changes, as moisture deficits may limit their ability to form peat and sequester carbon, and increase their vulnerability to fire. With peatlands currently acting as a substantial carbon sink, it is important to understand how peatlands responded to drier climates in the past.

Previous studies have identified a warmer and/or drier climate in Britain and Ireland ca. 6000-5000 BP, providing potential information for future mechanisms of peatland response to climate. This timeframe contains both the Hypsithermal/Neoglacial transition and the Mesolithic-Neolithic transition, which saw a relatively rapid expansion of farming and the first significant woodland clearance in both islands in the earlier part of the millennium. Climate change (cooling) at this time was driven at least in part by a reduction in Northern Hemisphere insolation, but increases in sub-fossilised timbers in Ireland suggest a drier climate from 5400 BP. Paired with the varying impact of land-use change, this period provides information for current trends influenced by anthropogenic change.

There remains, however, a level of uncertainty relating to the climate oscillations and resultant environmental change 6000-5000 BP. Here we present a multi-proxy palaeoenvironmental investigation of peat-cores from Northern Ireland. Core chronology is established through radiocarbon dating and tephrochronology, whilst testate amoebae, pollen influx and stable isotopes (carbon, nitrogen and oxygen) are used as palaeo-hydrology and -climate proxies. Bog system responses to observed changes and carbon capture are examined through plant macrofossil, bulk density, loss-on-ignition and carbon-nitrogen ratio analyses. Palynology is used to infer the importance of anthropogenic influences on vegetation cover in the surrounding catchment, including potential impact on the local water-table, as well as the relationship between changing land-use and climate. Thus, we consider 1) the timing and direction of environmental shifts within Northern Ireland peatland records in the mid-Holocene, 2) the response of the peatlands to climate changes in terms of hydrology, vegetation and carbon accumulation, and 3) how humans contributed or responded to the observed changes through land-use practices.

Impacts of a national road construction on peatland carbon dynamics in the Côte-Nord region, Eastern Canada

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The impact of tracks, winter roads or seismic trails on peatlands has been well-documented. Few studies, however, have focused on the impact of permanent and paved roads on peatlands, particularly as northern remote regions are being increasingly connected to road networks.

In this regard, sections of the national road (*Route 138*) in the Côte-Nord region (Québec) have been built since 1959, and the road will be expanded eastward over the next two decades to connect every village along the coast of the Gulf of St-Lawrence to the Labrador border. More than 400 kilometers will be constructed through territory that, in some sections, is densely covered by peatlands.

We aim to document the response of road construction on carbon dynamics in the threatened peatlands using a chronosequence approach. Along 120 kilometers of road, we examine vegetation and hydrological changes, as well as dust inputs and carbon accumulation in peatlands along four segments of different ages (1991, 2005, 2011 and yet to be constructed). During summer 2022, peat monoliths (50 cm, n = 24) were extracted 5, 25 and 100 m from the road along two perpendicular transects in each road segment. An additional 100 cm core was collected at each road segment for comparison with undisturbed conditions (n = 4). Surface vegetation, water table depth, pH and microtopography were documented at each station, and a water level logger was installed to record continuous water table depth variability on either side of the road. Preliminary results show that the hydrology of the peatlands is more impacted on the downstream sections. Loss-on-ignition results from the 24 short cores show important dust peaks at all 5 m plots, particularly downstream, which decrease with increasing distance from the road. At 100 meters, dust is mostly absent within the peat stratigraphy. Further analyses will investigate whether dust inputs have modified peat chemistry, and chronological control (radiocarbon, ^{14}C and radiometric lead-210 dating, ^{210}Pb) will allow for recent peat accumulation reconstructions along with vegetation succession and water table variations using respectively plant macrofossil and testate amoebae analyses.

Peatland records of recent (last ca. 250 years) climate change in the North of Ireland

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The North of Ireland holds great potential for the development of peatland-derived palaeoclimate records, reflecting: (i) the significant cover of ombrotrophic peatlands (>25,000 ha), which are responsive to hydro-climate fluctuations; (ii) the sensitivity of the region to changes in westerly airflow and frontal systems in the North Atlantic region; and (iii) the availability of instrumental records of climate change (>200 yr), which provide a basis for calibration of proxy records. We present hydrological reconstructions from nine ombotrophic peatlands spanning the last ca. 250 years based on testate amoebae, plant macrofossil remains and other proxies. These are chronologically constrained via AMS ^{14}C dating and the presence of a series of well developed tephra layers. The records show a high degree of similarity, especially in the last ca. 100 years, with synchronous changes occurring at all sites. Allogenic controls, notably climate forcing, rather than local internal disturbances, are suggested to be the dominant driver of the inferred hydrological changes. A phase of cool and/or wet conditions predominates from ca. AD 1750 until the late 1800s/early 1900s, probably reflecting the end of the Little Ice Age. Rapid drying is then recorded, and whilst the timing of the onset varies locally, this is prominent at all sites from AD 1940. The testate amoeba-derived hydrological fluctuations are validated through statistical comparisons with instrumental climate datasets. Strong correlations are observed between the hydrological records and summer temperatures, and to a lesser extent summer precipitation, indicating that the interaction of summer seasonal temperature and precipitation have a major influence on peatland-hydrological change in the region. Comparisons with climate proxy-records from elsewhere in NW Europe suggest that the recent drying observed in the region's peatlands is part of a climatic shift with wide spatial extent, although the exact timing shows minor variations.

Mid- to late Holocene mineral deposition and peat decomposition in the Faroe Islands using geochemical proxies: disentangling storm signals from volcanic eruptions

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Climate projections the North Atlantic region remains uncertain, as the forcing mechanisms of large-scale climate patterns like the Atlantic Meridional Overturning Circulation (AMOC) and the North Atlantic Oscillation (NAO) on longer time-scales remain to be fully understood. Paleoclimatic studies can decrease this knowledge gap and constrain model projections. An ideal location for such studies are the Faroe Islands, where temperature, precipitation and storminess variation are determined by the AMOC and NAO. With the earliest human settlement set around 6th century CE, the Faroe Islands offer a unique opportunity to reconstruct past climate changes with minimal anthropogenic disturbances. Despite this, terrestrial paleoclimatic reconstructions from the Faroe Islands are few and those that exist are mostly focused on biological proxies. Based on this, there is a need to improve the spatiotemporal coverage and the range of proxies studied at this climatically strategic location. Here, we investigate inorganic climate proxies in a peat core representing the last ~8000 years from the Faroese mire complex of Mýrarnar. Focusing on past variation in peat decomposition and mineral deposition, we analysed for elemental geochemistry (WD-XRF), mineralogy (XRD, SEM-EDS and ATR-FTIR), loss on ignition and bulk density. The degree of peat decomposition, here based on halogen contents and bulk density, generally increases with time. This indicates that the Holocene climate of the Faroe Islands became gradually drier. Eight mineral deposition events are identified by increased lithogenic element and mineral input, with peaks dated to 7790, 5740, 4440, 4130, 3740, 2800, 1960 and 820 cal. yr BP. At least three of these are dominated by tephra deposition and can be linked to known tephra horizons in the Faroe Islands. Whether the remaining events represent volcanic or climatic signals is currently unresolved, with a possibility that tephra dominates the geochemical proxy data. This calls for continued characterization of the mineral deposition events, possibly aided by statistical analysis, that can allow extracting climatic information in areas dominated by volcanic activity.

Developing a new testate amoeba-based hydrological transfer function for permafrost peatlands of Western Siberia

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Large areas of permafrost peatlands in Western Siberia store a significant amount of carbon on a global scale that is now under threat due to anthropogenic global warming. About 20-60% of frozen soil in Western Siberia is exposed to rapid thawing, which contributes to the destruction of characteristic palsa landscape and the expansion of thermokarst lakes or fens. Permafrost responds variously to environmental changes due to the complex climate-ecosystem interactions driving its formation and degradation. Information about past environmental transitions in Western Siberia is crucial to understand current changes, but knowledge about it still needs to be extended. Therefore, in this study, we aimed to build a hydrological testate amoebae (TA) transfer function (TF) from the Khanymei area to reconstruct past hydrological conditions in permafrost peatlands. Additionally, we wanted to integrate information about TA communities dwelling in lichens with the calibration data set and test their influence on TF performance. In the summer of 2019, 75 surface samples of *Sphagnum*, vascular plants, and lichens (genus *Cladonia* sp.) from the above active layer or permafrost were collected. Moreover, one peat core was extracted from the same area to perform the quantitative depth to the water table (DWT) reconstruction. The transfer function was developed on two datasets: all samples (n=75) and only bryophytes samples (*Sphagnum* and brown mosses) with *Cladonia* sp. excluded (n=55). We were able to confirm that the presence of *Cladonia* sp. lichens on the surface of the peatland affects the typical transition of TA community structure along the microtopographic (wet-dry) gradient. Both developed TFs showed satisfactory results. Even though the TF constructed on all samples performed better, it nevertheless provided a more accurate representation of the current vegetation conditions on the Khanymei peatlands. Lichens (e.g.: *Cladonia* sp.) predominate as a vegetation type and are an essential indicator of the permafrost state. We conclude that TF containing local environment features may be better adapted for the quantitative reconstruction, especially in the newly explored permafrost area of Western Siberia.

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Climate-driven ecosystem changes – comparison of boreal peatlands response from Eastern Canada and Western Siberia

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Northern hemisphere peatlands occupy only 2,5% of the land surface but store about 415 +/- 150 Pg C (~21% of global soil C), with the majority accumulated in boreal and subarctic biomes of Canada and Western Siberia. Present-day global warming threatens these huge C stocks, which have been shifting from the current sink to a source for the atmospheric C content. We hypothesize that the magnitude and direction of changes in peatlands differ between regions due to the modifying local and regional hydroclimate conditions. A recent comparative study indicates that the hydrological response pattern of permafrost peatlands to climate warming could be divergent. This study's objective is to compare the response of peatlands located in the discontinuous permafrost zone of Western Siberian (Khanymei region) to peatlands located in the isolated permafrost zone of Eastern Canada (north shore of the Gulf of St. Lawrence). These regions are characterized by different hydroclimatic conditions influencing former permafrost aggradation and current degradation. Processes related to permafrost degradation significantly affect Western Siberian peatlands, which were exposed to the most substantial warming worldwide in the last decade. Along the north shore of the Gulf of St. Lawrence, peatlands are affected by changes in precipitation, seasonal surface freezing, the influence of the Labrador Current, and intense wind exposure. All factors mentioned above are being transformed due to anthropogenic global warming causing widespread changes in these ecosystems and their related C sink capacity. Our study aims to validate our hypothesis that the response of boreal peatlands to ongoing climate change may vary due to regional hydroclimatic conditions.

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Monitoring peatland changes at the Roman site of Magna, Northumberland, UK

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The Roman fort of Magna is one of the most well-preserved sites along the Roman frontier in Northumberland. The fort holds a commanding position as the junction between three Roman roads – the Stanegate, Military Way, and Maiden Way – and surveys have indicated that activity there stretched from c.AD 80/85 until the end of the official Roman occupation of Britain c.AD 410.

Magna has an extremely damage peat area, visual changes over the last 20 years have shown the peat is drying and stone work is emerging from the peat. In 2021 a programme of monitoring was initiated at the site, this includes underground sensors being used to collect data such as ground water levels, conductivity, oxidation-reduction potential, pH and soil moisture. Above ground an extensive weather monitoring station was also installed to collected data every 15 minutes. The importance of monitoring and creating prediction models for these conditions especially changes in soil conditions, can impact upon preservation and ultimate degradation of artefacts, losing them to future study.

Assessing the Timing of Shifts in Recent Carbon Accumulation Rates in Eastern Canadian Peatlands

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Recent and rapid changes in climate and permafrost thaw are affecting carbon dynamics in high-latitude peatlands. There is growing interest in evaluating the C sink potential of peatlands for conservation as nature-based climate solutions. However, rapid decadal-to centennial-scale changes are poorly understood, in part due to poor dating resolution in surface peat. Here, we evaluate the timing of vegetation shifts and rates of carbon accumulation for the past ~200 years peatlands for 64 cores from boreal and subarctic regions in Québec and Labrador (Eastern Canada). We used classical (Constant Rate of Supply - CRS) and Bayesian (Plum) approaches to model age-depth relationships from lead-210 (^{210}Pb) and radiocarbon (^{14}C) dates. Results highlight the important role of permafrost thaw in altering local peatland hydrological conditions, favouring new peat addition and especially *Sphagnum* growth in subarctic regions. While both models provide similar ages for the last century in complete cores, the CRS model tends to overestimate peat ages compared to Plum prior to ~1900CE. When applying either model, it is important to provide an estimate for the supported ^{210}Pb or the influx, which may be complicated by disturbance. While ^{210}Pb activity profiles are a clear indicator of disturbance in the peat column from permafrost thaw, the addition of independent dating markers (e.g., postbomb ^{14}C dates) is especially important to validate age-depth models. Finally, using Bayesian models also allows for posterior distribution analyses such as proxy data changepoints. The choice of age-depth model and user decisions can have important knock-on effects for interpreting timings of environmental shifts, as well as estimating the order of magnitude of C stocks for policy and conservation purposes.

Sphagnum spore and charcoal co-profiling reveals hydrological conditions and fire activities during the past 2000 years in Daxing'an Mountains, northeast China

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The Daxing'an Mountains are located at the northernmost tip of China. Here, at the end of the East Asian monsoon, scattered a vast expanse of peatland. As an important timber base and a high incidence area of fire in China, however, there is limited research in long-term change of hydrological conditions and fire occurrence in the region. The change of hydrological conditions and fire activities here over the past 2000 years reflects the process of climate change and human activities affecting natural ecosystems, thus will have great significance to predict future ecosystem changes under global warming climate. Using sediment records of *Sphagnum* spore and charcoal from three peatland profiles (PG, TQ, MG), we reconstructed hydrological conditions and fire history in the region during the past 2000 years. Results show that charcoal peak is negatively correlated with *Sphagnum* spore, confirming that drier hydrological conditions help produce frequent fires; in addition, charcoal peak is positively correlated with drought-tolerant pioneer taxa, such as *Pinus*, *Betula* and *Quercus*. Our results also revealed the occurrence of the Medieval Warm Period (MWP, AD 680-1300) and the Little Ice Age (LIA, AD 1300-1900) in the region. Three periods of greater frequency of fire with different hydrological conditions were detected over the past 2000 year: MWP (warm and dry), early LIA (AD 1300-1500) and late LIA (AD 1700-1900) (cold and dry). These more intensive fire activities coincide with the phases of drier hydrological conditions. Fewer fires have been identified in the middle LIA (AD 1500-1700) due to the cold and wet hydrological conditions. Fire frequency has been changed by intensive human activities over the past century.

PEATFLAMES: Identifying tipping points for ecosystem functioning of northern peatlands during the climate crisis

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Peatlands currently act as carbon sinks and stores. Still, warmer climate and changing weather patterns due to anthropogenic climate change could cause them to become carbon sources in some regions, exerting a positive feedback upon global climate. Warmer, drier conditions also make peatlands more vulnerable to wildfire, which have increased in frequency and intensity across many peatland-covered areas in the Northern Hemisphere, including permafrost regions. Such events may release vast quantities of formerly stable, ancient carbon over a very short period of time.

How northern peatlands will respond to climate change remains uncertain. This uncertainty has prevented peatlands from being included in many Earth System Models, despite their significance in the global carbon cycle. Understanding how past climate changes and anthropogenic activity have affected peatland ecosystem functioning in the past will allow us to better understand how peatlands may respond to future changes, reducing this uncertainty.

Our project aims to assess how warming, drought and wildfire have impacted the resilience of peatlands and permafrost in the Northern Hemisphere over the past c. 2000 years. Multiple cores taken across a latitudinal gradient spanning several countries across Europe (Poland, the Baltic states and Scandinavia) will be analysed using multiple palaeoecological proxies at high resolution to reconstruct past fire activity, hydrological dynamics and vegetation change. This will allow us to define baselines and threshold values for ecosystem shifts relevant to future projected changes in climate.

Coastal peat records: an exploration of potentials and problems

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Using the information contained in the organic matrix as well as the archived mineral content in parallel, we can acquire a continuous picture of past paleoenvironmental changes using peat sequences. Peat sequences from coastal ombrotrophic bogs are increasingly used for reconstructing *storminess* (a term encompassing both frequency and intensity) on centennial to millennial timescales, where greater quantities of coarser grained beach sand are deposited by strong winds during storm events. To date, grain size, ash content, elemental and spectral approaches have all been applied as proxies of increased wind intensities in peat sequences. Coastal environments are however, heterogenous and isolating climate signals in peat deposits can be complicated by e.g., past changes in sea level, dune development as well as landscape morphology and geometry.

To explore the potential impact this has on coastal paleoclimate records we turn to Islay, a small island located on the Scottish west coast. Islay is a perfect natural laboratory for paleoclimate and in particular, paleostorm studies, in that it has abundant coastal dunes and beaches with relatively thick peat deposits located closely downwind (<3 km). We also have the previously published Laphroaig peat paleostorm record, covering the last ~6 ka, available for comparison. We introduce the RSPB (~8 ka) and the Duich (~5 ka) records which have both been analysed for basic peat properties, elemental concentration, grain size and mineralogy as measured using a new mid-infrared spectrometry protocol. We test the coherence of the multi-proxy climate signals both within a single sequence and across the island as a whole by applying changepoint modelling to all three records; this identifies the depth/age of changes in proxies through Bayesian modelling approaches. We attempt to link any observed differences to the individual site settings and tease out controlling factors. We hypothesize that random, analytical and site-specific noise is best dealt with by applying the changepoint modelling. This can in turn be compared with available pollen and dune activity data from the island for a more wholistic paleoclimate reconstruction.

Improved chronology and palaeoecological interpretation derived from peat horizons interbedding the Late Glacial mineral sequence of the Klaklowo landslide fen (the Outer Western Carpathians, Poland)

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Klaklowo landslide fen developed within the subscarp depression of the Klaklowo landslide in the Beskid Makowski Mts. (the Outer Western Carpathians, Poland) at the earliest stage of the landslide formation. As a consequence, it possesses the Late Glacial sedimentary sequence of rarely occurring thickness reaching up 2.5 m, which bottom parts allows for dating the onset of landslide formation as well as for reconstructing palaeoenvironmental changes during Bølling and Older Drays climatic oscillations. Improved chronology based on the current AMS radiocarbon dates enabled us to clarify the age of the lowermost organic horizon (decomposed peat) occurring within the mineral sequence at 14,896-14,277 cal BP, which time span corresponds to Bølling climatic oscillation and is in agreement with the pollen data obtained from Klaklowo site.

As inferred from the results of plant macrofossil analysis, the identified zones of different plant taxa fit very well to climatically-conditioned changes in lithology of the sedimentary sequence. During Bølling Interstadial, when a thick interval of clayey silt was deposited, the local conditions were aquatic and poor in vegetation, what is confirmed by occasionally occurring macrofossils of Characeae, *Batrachium* sp. and *Zanichellia palustris*. Enrichment in different, mostly boggy, plant taxa at the depths of both organic horizons intercalating the mineral sequence reflects the process of water reservoir shallowing and vegetation encroachment. The lower peat horizon contains mostly seeds of *Juncus* sp., whereas the upper one, beside the predominating occurrence of *Carex rostrata* along with *Eleocharis palustris* and *Phragmites australis*, documents a slight transition in trophy, as suggested by the presence of oligotrophic *Eriophorum vaginatum* followed by the eutrophic *Urtica dioica* and *Thelypteris palustris*. Second organic horizon is overlaid by the 0.5 m thick Older Dryas mineral sequence, which is abundant in macrofossils of aquatic plants, e.g. Characeae and *Potamogeton* sp., confirming the existence of a permanent waterbody. The gradual overgrowing with sedges, brown mosses and birch, as well as the appearance of *Pinus sylvestris* in the uppermost part of the studied interval signalizes the onset of the Allerød warming.

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Quantitative reconstruction of surface wetness between 13.8 and 8.2 cal kyr BP in Hani peatland in the Changbai Mountains, Northeast China

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Peatlands are valuable ecosystems owing to their various functions such as storage of carbon, regulation of catchment hydrology, and in particular archives of environmental change. Peatlands began to develop widely since the last deglaciation, when have significant relevance to present climate changes. Quantitative reconstruction of peatland surface wetness changes, which is dominantly controlled by effective precipitation and thus closely associated with climate, has been a priority in Quaternary Science. In this study, we presented a high-resolution (20 years/cm) record of plant macrofossils from Hani peatland in the Changbai Mountains, Northeast China, where climate is mainly controlled by East Asian monsoon. The surface wetness of the peat sequence between 13.8 and 8.2 ka BP was quantitively reconstructed through a plant-based transfer function developed for this region. The reconstructed surface wetness described by depth to water table (DWT) reveal wet phase (DWT ≈ 10 cm) at Allerød period (from ~13.8 to ~12.3 ka BP), dry phase (DWT ≈ 13.2 cm) at YD stage (from ~12.3 to ~11.9 ka BP), a general wetting trend (DWT ranged from 10.3 to 8.0 cm) from ~11.9 to ~0.98 ka BP with a major dry shift (DWT ≈ 15.4 cm) at the stage from ~11.23 to ~11.15 ka BP, followed by an increased dry phase (DWT ≈ 14.1 cm) from ~0.98 to ~0.95 ka BP, and a general wetting trend (DWT ranged from 10.2 to 7.0 cm) from ~0.95 to ~0.82 ka BP. Compared with the climate changes revealed by pollen and stable carbon and oxygen isotopes from the same peatland, the surface wetness of Hani peatland responds well to regional climate change. Reconstructed peatland surface wetness provides an important basis for reconstructing past climate changes in this region, and also gives a reference for predicting mire surface wetness under global climate warming in the future.

A 13.5 ka record of environmental changes derived from Wawerner Bruch fen (Saar valley, SW-Germany)

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Wawerner Bruch fen (Saar valley, Rhineland-Palatinate, SW-Germany) has formed in an abandoned meander bow of Saar River. Peat cores were retrieved from the central part of the extended peatland and analysed by applying a multi-proxy approach (micro-/macrofossil analyses, XRF, total carbon and total nitrogen measurements).

The beginning of fen peat accumulation is evidenced at ca. 13,400-13,490 cal. BP, during the Older Dryas/ Allerød interstadial. The study focuses on the vegetation and settlement dynamics of the lower Saar valley, an area of exceptional Celtic and Roman history.

During Allerød and Younger Dryas, the fen was dominated by an open vegetation with dominating sedges, replaced by *Salix* towards the end of the Allerød. Local forest vegetation was dominated by cold-tolerant tree species like *Pinus sylvestris*, *Betula* (partly *Betula nana*) and *Salix*. Open landscapes with steppe vegetation were the prevailing vegetation type of this period. Between the Preboreal and the Boreal, the vegetation shifted from boreal Birch-oak-forests to an open woodland with high abundances of hazel. During the Atlantic period, a wetter phase led to the reestablishment of a *Salix* forest-mire within the peatland. From 5000 cal. BP on, alder has begun to show increasing percentages in the pollen record, and the last 4000 years show a stepwise establishment of a prevailing *Alnus* fen. The Romans supposedly cleared the alder forest, but it re-established during the migration period. Until 1000 cal. BP, the pollen data show highly fluctuating percentages in zonal forest vegetation with conspicuous correlations within typical tree species: *Fagus sylvatica*, *Carpinus betulus* and *Corylus avellana*, or *Betula* and *Quercus*. During the Middle Ages, the decline of nearly all tree species, especially *Fagus* is evident, in favour of open-land cultivation. During the Little Ice Age, the agricultural land was continuously used as grassland. In the near past, the construction works of the Saar channelization led to severe drop of the peatlands´ water level. Currently, fallow lands with monotone *Filipendula ulmaria* stands and *Salix* bushland are among maintained sedge reeds, which characterize today the landscape of the Wawerner Bruch.

Two millennia of fire activity: influence of climate and people in a peat-bog from Western Romanian Carpathians

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Fire is an episodic phenomenon driven by the interplay between climate, terrain, vegetation (fuel moisture, availability, composition, structure) and human activities. This fine-scale process is a key component in natural ecosystems and has been essential in human evolution and an important tool for anthropogenic land cover. More recently, in the face of current climatic changes, with the increasing fire-promoting conditions combined with increasing human activities (e.g., rural land abandonment, flammable trees), areas such as central and eastern Europe where historically, fires were rare are expected to experience an increase in fire events. Paleofire data allow us to study the trend in fire frequency at different timescales and are necessary to understand better the connection with climate variability and human activities and assess the role of fire in shaping the landscape. The main aim of this study is to assess the past relationship between changes in fire, human activities (mining, pasturing, forest clearance), and climatic variability over the past 2600 years in the mid-elevation landscape of Western Romania. Here, we focus on the Mluha peat sequence located at 1240 m in the Apuseni mountains. We applied a combined approach based on macro- and micro-charcoal counting, pollen analysis, 14C dating, high-resolution geochemistry, archaeological information and climatic (temperature, precipitation) modelled data. Our multi-proxy results show three periods of fire activity, with the first interval between 2600 to 2000 cal yr BP characterised by moderate fire activity. The major fire event registered in our record around 2100 cal yrs BP might have been driven by Dacian populations; likely, they used fire for forest clearance and pastureland management. However, more favourable climatic conditions for fire activity can't be ruled out. During Roman Antiquity-Migration Period, fire activity was relatively low, but the fire events corresponded with a major vegetation reorganisation suggesting that human activities were responsible for setting fires. The Medieval times are outstanding, the intense fire activity is paralleled by the establishment of mountain pastures and large-scale landscape openings, as shown by pollen data, and intensified mining activities, as shown by geochemical records. Our reconstructions provide greater insights into the long- and short-term climate-human-fire relationships.

Antarctic Peninsula peatbank oxygen isotope values during the warmest summer and in the oldest continental profile

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The Antarctic Peninsula region is warming and ice-free areas are expanding, resulting in the re-exposure of dead plants and overall greening with new vegetation. During austral summer 2020, during record-setting warm conditions, we collected snow, water, plant, and peat samples from 15 sites from 62 to 65°S with support from the RV Laurence M Gould. Values of δ^2H and δ^{18}O in late-lying snow and surface waters were similar to local meteoric-water-line values. Plant water, however, showed substantial evaporative enrichment in δ^{18}O, regardless of species. We measured peatbank stratigraphic cellulose δ^{18}O extracted from subfossil leaf tissue of a single plant species at two sites. In the deepest (2m) and oldest (4 ka BP) peatbank south of 61°S, δ^{18}O values varied across a range of 6‰, suggesting previous warm summers with high evaporation, particularly around 2.3 ka. This record extends the peatbank history of terrestrial hydroclimate in the central Antarctic Peninsula region by ~2000 years.

Acoustic and physical properties of the Nakdong River valley and delta sediments

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The core samples collected from the Nakdong River valley and delta areas were used to characterize acoustic and physical properties in relation to depositional and lithological units. The acoustic and physical properties data were readily classified in good agreement with the depositional units: Units I, II, III, and IV in ascending order. In other words, the variations in the physical properties reflected well the relative characteristics of the depositional units. Overall, Unit I was characterized by high values of the data such as compressional wave velocity (1683 m/s on average), wet bulk density (2.17 g/cm^3 on average), and shear strength (41.2 kPa on average), whereas the porosity of Unit I was the lowest (approximately 35%). Moreover, the physical properties other than grain density reflected well the characteristics of each unit, characterized by gradual change from Unit I to Unit IV. Nevertheless, based on the acoustic and physical property data, the lithology, rather than compaction with burial depth, likely played an important role in the variation of acoustic and physical properties of each unit. These results suggest that the acoustic and physical properties were mainly controlled by depositional processes at the time of deposition. The velocity anisotropies were mostly negative without a significant effect of compaction with burial depth. Nevertheless, the cracks occurring along bedding planes after coring were responsible for low horizontal velocities and negative anisotropies.

First results from two research drill-cores in the former Salzach and Isar-Loisach foreland glacier areas (Bavaria, Southern Germany).

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The multinational pan-alpine research project ICDP - DOVE (International Continental Scientific Drilling Program - Drilling Overdeepened Alpine Valleys) currently investigates overdeepened structures in the Northern Alpine Foreland (NAF). This presentation focuses on two depositional structures in the central part of the NAF. The first investigated overdeepened basin presented here is located west of Freilassing and was formed by the former lobe of the Salzach foreland glacier. A 136 m long core (ICDP-5068_4), drilled near Neusillersdorf consists of 117 m of Quaternary sediments on top of 19 m of Flysch bedrock. The Quaternary sediments can be further divided into a base diamicton (117-115 m) overlain by fine-sand/silt sized laminated sediments (115-27 m) that are covered by sandy-gravel/diamicton sediments (27-0 m). The second overdeepened structure discussed here is situated south of Munich and was eroded by the Isar-Loisach foreland glacier. Near the town of Schäftlarn a drill-core (ICDP-5068_3) consisting of 199 m of Quaternary sediments was retrieved. In this case the Molasse bedrock was not reached. The drill-core can be divided into diamicton remnants (198.8-198.5 m) at the base, overlain by silty sand with dropstone presence (198.5-184 m), again overlain by partly laminated silt (184-170 m), fine sand interlayered with silt and dropstones (170-158 m) and partly laminated silt with decreased presence of dropstones (158-115.5 m). The sequence is topped by sandy-silty gravel (115.5-6 m) and a clast supported diamicton (6-0 m) below the surface. We present current results and progress of the multi method analysis of the two drill-cores, including but not limited to, sedimentological and sediment-petrographic analyses, geophysical logging and geochronology based on single grain luminescence dating of potassium-rich feldspar using a pIRIR225 (post infrared, infrared stimulated luminescence @ 225°C) single aliquot regenerative (SAR) dose protocol. The investigated research drill-cores were kindly provided by the Bavarian Environment Agency (LfU).

Are sediments of the glacially overdeepened Tannwald Basin seismically anisotropic?

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Glacially overdeepened valleys / basins were excavated by glaciers below their fluvial base level and filled up by sediments. One such basin in the northern foreland of the European Alps is the Tannwald Basin (ICDP site 5068_1), where three boreholes were drilled that reached the Quaternary base at 153 to 158 m depth. In this environment, fine layering, a preferred depositional direction or the alignment of clasts as well as glaciotectonic shearing and the overdeepening itself through an alignment by load can cause seismic anisotropy, i.e. a directional dependency of wave propagation. Vice versa, seismic anisotropy can be interpreted in terms of sedimentation processes. To investigate the sediments regarding this effect, the boreholes were arranged in an isosceles triangle with N-S and W-E orientation of the two short edges (ca. 30 m length). This setup allows us to study not only polar but also azimuthal anisotropy through a crosshole experiment and an inverse walk-around VSP (vertical seismic profiling).
We investigate the hypothesized anisotropy by means of polarization analysis looking for a phenomenon called shear-wave splitting. For this purpose, we rotate the three-component data into a radial, a transverse and a vertical component using energy maximization. Afterwards, the direction of particle-motion, i.e., polarization, can be depicted by hodograms that indicate anisotropy. For noisier parts of the dataset, we apply more sophisticated methods, like eigenvalue or singular value decomposition. Furthermore, we give an outlook on how the type of anisotropy is determined and its degree quantified by the results of polarization analysis as well as simulation and inversion of the seismic wavefield. As one of the three boreholes was completely cored, the results can be interpreted in terms of the known lithostratigraphy.

ICDP Project DOVE (Drilling Overdeepened Alpine Valleys): The Basadingen Borehole (ICDP 5068_2)

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The panalpine project "DOVE" (Drilling Overdeepened Alpine Valleys), co-funded by the International Continental Scientific Drilling Program (ICDP), comprises a series of drill holes into overdeepened glacial troughs around the Alps that were formed by subglacial erosion during past glaciations. The sedimentary fill of these troughs, consisting of multiple stacked and nested glacial sequences, provides promising archives for deciphering when glaciers reached certain parts of the Alpine forelands. The combined data from all DOVE sites comprising synchronous or asynchronous ice advances and ice extents in the different regions, will provide a crucial database for improved understanding of the patterns in glacial-interglacial paleoclimates and landscape evolution during the Mid-Pleistocene.

The overdeepened Basadingen Trough in Northern Switzerland is one of the DOVE targets (5068_2). The area of the overdeepening was glaciated by a western lobe of the Rhine Glacier during several Middle to Late Pleistocene Glacials. The trough is a narrow, ca. 250-300 m deep, SSE-NNW trending structure, forming a so-far poorly understood, old overdeepened valley system that connected the present-day Thur Valley with the Rhine Valley – a connection that does not exist in the present surface morphology and that was probably active only during the Middle Pleistocene. The drill core supports the interpretation of the high-resolution 2-D seismic, which indicates that the valley fill consists of deposits from multiple glaciations, thus, verifying the Basadingen Trough an ideal target for DOVE. Based on the correlation and integration of the various existing data (e.g. 2D seismics, sedimentological description, core-to-seismic correlation, geophysical logs of the borehole and drill core, geotechnical properties, chronological data …), we aim to establish a model for the glaciations that affected the Basadingen Trough and the Northern Alpine foreland in general.

Drilling Overdeepened Alpine Valleys: First results from the Tannwald Borehole (ICDP 5068_1)

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The panalpine project “DOVE” (Drilling Overdeepened Alpine Valleys), co-funded by the International Continental Scientific Drilling Program (ICDP), comprises a series of drill holes into overdeepened and filled glacial troughs proximal to the Alps that were formed by subglacial erosion during past glaciations. The sedimentary fill of these troughs, consisting of multiple stacked and nested glacial sequences, provide promising archives to decipher when glaciers reached certain parts of the Alpine foreland. The combined data from all DOVE sites, comprising synchronous or asynchronous ice advances and ice extents in the various regions, will eventually provide a critical database to evaluate patterns in glacial-interglacial paleoclimates and landscape evolution back to the Mid-Pleistocene.

The Tannwald Basin is an overdeepened bedrock trough in the distal part of the Rhine Glacier landscape north of Lake Constance. Previous drilling and a seismic survey suggest that the Tannwald basin has a maximum depth of 240 m below the actual surface and hosts two generations of glacial infill. For DOVE, one core and two flush drillings on the western flank of the basin have been carried out from April to November 2021 (5068_1A, B, C). All drillings reached bedrock, i.e. Tertiary Molasse, and the core drilling also recovered 10 m of Molasse down to a final depth of 166 m. The cores in the Tannwald basin recovered sediments that show basal diamicts and sands overlain by a 110 m-thick succession of fine deposits with dropstones. These are overlain by 39 m of sands, gravels and coarse grained diamicts. Soft sediment deformation is also observed, which may represent glaciotectonic activity or mass movements. We will present a detailed sedimentological description of the core, which will be combined with 2D seismics, borehole and core geophysics, geotechnical properties, pollen analysis, OSL dating, cosmogenic nuclides dating, and noble gas dating of pore water to constrain the glacial history of the basin.

Drilling in the Baza Paleolake (SE Spain): Understanding Early Human Dispersal in the Western Mediterranean

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Long, continuous sedimentary sequences are essential to contextualize hominin fossils and early Paleolithic sites. Both, building a solid chronological framework and exploring the role of environmental forcing in shaping human evolution are fundamental questions that demand such continuous sedimentary records. The eastern part of the Guadix-Baza Basin hosts the largest, southernmost paleolake in Europe and holds an invaluable sedimentary archive for the Plio-Pleistocene period. The paleolake's rich and extensive depositional sequence holds the key to understanding the former gateway between the Atlantic Ocean and Mediterranean Sea (the Betic Corridor) before the early-Pliocene connection at Gibraltar, providing an unprecedented paleoclimatic and paleogeographic record of the region throughout the Cenozoic. Lastly, is the only basin in Western Europe that holds human presence near a continuous fluvio-lacustrine environment. The Baza Formation includes lacustrine–palustrine carbonates and alluvial sediments, and it is known for hosting numerous Plio-Pleistocene paleontological sites, including lithic artifacts. In 2022 we launched a new drilling program for obtaining continuous sedimentary records from this basin, since its deposits are otherwise partially exposed along degraded outcrops. Two complementary boreholes were drilled at the archeo-paleontological site of Barranco León (Orce). The locality is known for containing a significant Oldowan lithic assemblage and a human tooth, in association with a rich and diversified faunal assemblage made of large and small mammal remains. Dated to around 1.4 Ma old, the site documents some of the earliest evidence of human presence in Europe. The drilling resulted in the recovery of ca. 80 meters of continental sediments, including limestones and siltstones belonging to the lacustrine Baza Fm. Core sections are initially passed through a Geotek Multi-Sensor Core Logger that provides a suite of geophysical measurements, including bulk magnetic susceptibility and natural gamma. Cores are then either split or sliced to obtain samples for paleomagnetism, XRF, meteoric ^{10}Be and other analyses (e.g., grain size, carbonate contents, δ^{18}O, pollen, stable isotopes analyses, etc.) in order to characterize the sedimentary record. Our initial results, mostly based on magnetic reversal stratigraphy, provide new constraints to the chronology of the lake sediments and hence to the archaeological site of Barranco León.

Late Pliocene North Atlantic Current temperature records highlight millennial-scale climate variability prior to the Quaternary

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The late Pliocene marks the initiation of the Northern Hemisphere Glaciation (NHG) and major transition from a relatively stable warm climate to more pronounced glacial-interglacial climate variations. The warm, salty water carried poleward by the Gulf Stream and subsequently the North Atlantic Current (NAC) plays a key role in controlling or modulating North Atlantic climate change. Its Pliocene changes are considered to precondition the initiation of the NHG. To evaluate the climatic effects of the NAC changes at the beginning of the late Pliocene, we produced millennial-scale planktonic foraminifers Mg/Ca-derived surface and subsurface water temperature (Mg/Ca-T) records at IODP Site U1313 (41°N, 33°W, 3412m), an ideal location to monitor past NAC changes, for the interval from 3372 to 3654 ka. The Mg/Ca-T of mixed layer species *Globigerinoides ruber*, interpreted as reflecting summer surface water conditions, varies within the narrow range of 20.5–24 ℃ without clear glacial-interglacial cycles. Subsurface water dwelling *Globototalia hirsuta*
exhibits Mg/Ca-T in the 16–19.5 ℃ range, following a pattern similar to *G. ruber*. The temperature difference between these two species is relatively constant with an average of 4.5 ℃. Surprisingly, the Mg/Ca-T record of mixed layer species *G. bulloides*, interpreted as representing spring conditions due to its comparability with the $U^{k'}_{37}$ temperatures, shows large abrupt variations within a wide range between 15℃ and 23 ℃, but also a general trend similar to those of *G.ruber* and *G.hirsuta*. We interpret the intervals where *G.bulloides* Mg/Ca-T shows values similar to *G.ruber* Mg/Ca-T as reflecting reduced seasonality and consistent strong NAC presence at Site U1313. By contrast, intervals of *G.bulloides* Mg/Ca-T reaching values like subsurface species *G. hirsuta* indicate strengthened seasonality and a deepened spring mixed layer. We conclude that the NAC shows prominent oscillations at the beginning of the late Pliocene and the repeatedly weakened NAC periods may have contributed to the fast growth of northern hemisphere ice sheets.

Cyclostratigraphy applied to ICDP downhole logging data: potential and methodological considerations

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Extensive borehole logging datasets have been collected for commercial and scientific purposes, but studies exploring their full potential considering time series analysis are scarce. Even in some ICDP projects, borehole logging data has the potential to contribute relatively fast available proxy data and first age-model constraints. Here, we briefly summarize the key properties of borehole logging data and pitfalls in the context of time series analysis and cyclostratigraphy. We demonstrate its applicability in several case studies. Further, we discuss various methodological/statistical approaches, and provide arguments for analysis beyond cyclical components via Fourier Transform. Especially assessing hierarchical cycle patterns in logging data, and relating these to insolation properties provides strong stratigraphical constraints in some cases.

Evidence for Last Interglacial hydroclimate and vegetation changes in subtropical Southeast Africa from plant leaf wax stable isotope analyses on IODP Site U1477 sediments

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Future global warming is commonly considered to significantly affect hydroclimate conditions in subtropical Southeast Africa, but the extent of this impact is still debated. Investigating regional hydroclimate variability during warmer-than-present periods in the past such as the Last Interglacial might therefore provide important information about the hydroclimatic response to future warming. In addition, improved knowledge of the region's Last Interglacial hydroclimate can also enhance our understanding of possible controls of the cultural evolution and migration of the first anatomically modern humans. To reconstruct Last Interglacial hydroclimate and vegetation changes in subtropical Southeast Africa, we analysed the stable hydrogen (δ^2H) and carbon isotope composition (δ^{13}C) of long-chain *n*-alkanes preserved in deep-sea sediments recovered at IODP Site U1477, located ~85 km off the Zambezi River delta in the Mozambique Channel. As the δ^2H of the long-chain *n*-alkanes, which are major components of the epicuticular waxes of higher terrestrial plants, primarily reflects amount-controlled changes in the δ^2H of precipitation, it can be used to reconstruct hydroclimate variability in the Zambezi River catchment through time. In addition, the *n*-alkane δ^{13}C allows to trace past hydroclimate-driven vegetation changes, i.e. variations in the relative abundance of C_3 (e.g. trees) and C_4 plants (e.g. savanna grasses). Already during the terminal phase of the Penultimate Glacial we observe a decrease in *n*-alkane δ^2H, indicating increasing humidity in subtropical Southeast Africa. Fairly humid conditions prevailed thereafter, interrupted by two distinct episodes of relatively high δ^2H values at about 125–119 and 105–112 ka BP, most likely reflecting intervals of pronounced dryness. This is in good agreement with parallel reductions of the *n*-alkane concentration in the sediments, indicating reduced supply of terrestrial organic matter by the Zambezi River. After ~105 ka BP, *n*-alkane δ^2H values further decreased, likely reflecting progressively increasing humidity during the transition into the Last Glacial. To conclude, our results document a considerable hydroclimate variability in Southeast Africa across the Last Interglacial with two pronounced dry episodes. These might have been contemporaneous with wet intervals in Northeast Africa, together fostering the episodic northward migration of early modern humans.

New insights into marine ecosystem changes during the early to middle Pleistocene at IODP Site U1387, southern Portuguese margin

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Centennial-scale planktonic and benthic foraminifera stable isotope and alkenone sea-surface temperature (SST) records from IODP Site U1387 (36°48´N 7°43´W; 559 m water depth), drilled into the Faro Drift on the southern Portuguese margin, record paleoclimatic changes in this transitional zone between the subtropical North Atlantic and the Mediterranean Sea. With the paleoclimatic framework established for Marine Isotope Stage (MIS) 16 to MIS 52, we are now able to evaluate how the marine ecosystem responded to the paleoenvironmental changes prior to and during the Early to Mid-Pleistocene transition (EMPT). For that we are studying the planktonic and benthic foraminifera fauna as well as the nannofossil flora during selected time periods.

Early Pleistocene interglacial periods prior to the EMPT exhibit warmer SST with the planktonic foraminifera fauna indicating a strong influence of subtropical waters. The common occurrence of tropical species even hints to a persistent contribution of tropical waters and thus the northward expansion of the subtropical gyre. This is supported by higher contributions of warm water taxa to the nannofossil flora. Subtropical gyre influence persisted during the EMPT, but at a reduced level, pointing to a contracted subtropical gyre. Extreme cooling events marking most of the abrupt glacial/interglacial transitions (e.g., MIS 22/21, MIS 26/25, MIS 48/47) were associated with a significant influx of cold-water species *N. pachyderma* and *C. pelagicus ssp. pelagicus*, respectively, and thus a southward advance of subpolar waters. The benthic foraminifera fauna, on the other hand, responded mostly to changes in food flux sources and thus productivity changes in the prevailing surface waters, although short-term response to bottom current velocity increases, e.g. Mediterranean Outflow Water presence, were also recorded.

Deep Dust: Exploiting Dust and Loess Archives in Deep Time to Probe Permian Continental Climate

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Quaternary lake and loess deposits are amongst the highest-fidelity archives of continental paleoclimate, and form an excellent target for coring. Analogously, these sediment types should archive high-fidelity records in deep time, albeit less recognized. Here, we present a plan for continuous coring of the thickest suspected loess accumulation in Earth history, spanning the 50 My encompassing both Earth's last icehouse collapse, and largest extinction known.

The climatic, biotic, and tectonic events of the Permian are amongst the most profound in Earth history. Global orogeny leading to Pangaean assembly culminated by middle Permian time, and included multiple orogenic belts in the equatorial Central Pangaean Mountains, from the Variscan-Hercynian system (east) to the Appalachian and Ancestral Rocky Mountains (west). Earth's penultimate global icehouse peaked in the early Permian and largely collapsed soon thereafter, transitioning to full greenhouse conditions by later Permian time, thus archiving the only example of icehouse collapse on a fully vegetated Earth. The Late Paleozoic Icehouse was the longest and most intense glaciation of the Phanerozoic, with hypothesized low-elevation glaciation posited for both eastern and western tropical Pangaea during early Permian time. Reconstructions of atmospheric composition record the lowest CO_2 and highest O_2 levels of the Phanerozoic, with average CO_2 levels comparable to the Quaternary, rapidly warming climate. A global megamonsoon developed and the tropics aridified. Extreme environments are well documented in the form of voluminous dust deposits, acid-saline lakes and groundwaters, extreme continental temperatures and aridity, and major extinctions/extirpations, ultimately culminating at the Permo-Triassic boundary with the largest extinction of Earth history.

We seek to elucidate paleoclimatic conditions and forcings through the Permian at temporal scales ranging from millennial to Milankovitch and beyond by acquiring continuous core in continental lowlands known to harbor complete records dominated by loess and lacustrine strata. Our initial site is in the midcontinental U.S.— the Anadarko Basin (Oklahoma), which harbors a complete continental Permian section from western equatorial Pangaea. We will also address the nature and character of the modern and fossil microbial biosphere, Mars-analog conditions, and exhumation histories of source regions.

Timing and progression of Dansgaard-Oeschger events in Central Europe based on three precisely dated speleothems from Bleßberg Cave, Germany

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Speleothems can be dated with unprecedented precision using U-series disequilibrium methods and provide numerous climate proxies, such as stable oxygen ($\delta^{18}O$) and carbon isotopes ($\delta^{13}C$) or trace elements, resulting in long, sometimes continuous climate proxy records. Therefore, speleothems have great potential for reconstruction of past climate variability during Marine Isotope Stage (MIS) 3 and precise determination of the timing and duration of Dansgaard-Oeschger (D/O) events. While first discovered in Greenland ice cores, various speleothem records around the globe provided clear evidence for the supra-regional character of the D/O events. However, MIS 3 speleothem records from Central Europe are very limited. Here we present three spleothem (flowstone) MIS 3 records from Bleßberg Cave, Germany.

All flowstones show episodic growth with distinctive, partially very thin (<2 mm) growth phases, interrupted by visible hiatuses consisting of detrital material. Precise and accurate $^{230}Th/U$ dating of the individual growth phases is challenging due to potential detrital contamination from these layers. Combining different sampling and analytical techniques, we were able to date even the thinnest growth layers with very high precision, i.e., 2σ-age uncertainties of at most a few hundred years.

The timing of the growth phases aligns with several D/O events, which have not been recorded in other Central European speleothems yet. The $\delta^{18}O$ and $\delta^{13}C$ records of all three flowstones are highly correlated which suggests a dominant process influencing both isotope systems. Comparison with the Sr and Mg records provides evidence for a strong influence of Prior Calcite Precipitation (PCP) in the aquifer above and inside the cave on the stable isotope and trace element signals. In addition, all proxy records are interpreted as evidence for past changes in precipitation and vegetation density and document a clear trend from more humid climate during early MIS 3 (ca. 57 – 50 ka) to less humid conditions during mid and late MIS 3 (ca. 45 – 30 ka).

Our multi-proxy approach thus allows us not only to precisely determine the timing, duration, and progression of several D/O events, but also to deepen our general understanding of climate variability during MIS 3 in Central Europe.

Modelling alluvial peatland development at Holocene timescales

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It is well known that accumulation rates in peatlands are higher for short-term measurements, compared to long-term rates based on peat stratigraphy. When looking for effective management practices, insight in peatland dynamics at longer timescales is imperative. Various models have been developed to simulate the long-term dynamics of peatlands and applying such models can be a useful tool to evaluate the interactions between peat growth and environmental changes or management practices. While many of these models assume peat to develop in a geomorphically stable setting, this assumption is not valid for floodplains. For example, many river valleys in Europe have known phases of peat growth throughout the Holocene, influenced by the geomorphic behaviour of the local river channel(s) and associated sediment dynamics. As the effects of the river geomorphology is currently lacking in peatland models, a proper assessment of the relationship between peatland development and river dynamics remains difficult.

Here, we constructed a new peatland model, developed specifically for floodplains, by coupling a modified version of an existing peatland model (Digibog 1D) with a water balance model (STREAM). By combining this new tool with pollen-based land cover and climate reconstructions and reconstructions of the Holocene stratigraphy, detailed simulations of the peatland dynamics were made for several case-studies. This modelling framework allows to study the effect of changes in river network properties on peat growth and the associated carbon dynamics. The model was applied to contrasting case-studies, located in the European loess belt (Dijle river) and sand belt (Grote Nete and Zwarte Beek rivers). The results indicate that river discharge variations as a result of climatic and land cover changes have a limited effect on alluvial peat growth as discharge differences mostly impact the magnitude of peak events. In contrast, the configuration of the local river network (the number of channels and their position relative to the peat surface) have a strong impact on the peat thickness. These results indicate that management focussing on the river network configuration such as reducing the number of channels or raising the river bed can be effective strategies to promote long-term alluvial peat growth.

Arctic peatland carbon dynamics and extent with climate change

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The Arctic is warming at more than double the rate of lower latitudes, leading to rapid and widespread ecological change. Arctic peatlands are carbon-rich ecosystems where the net carbon (C) uptake by plants has exceeded losses to microbial decomposition over decades, centuries, or millennia. Permafrost thaw associated with warming exposes previously frozen peat to greater and faster decomposition. However, increasing temperatures will also lead to greater plant productivity and a lengthening of the growing season that may result in greater C accumulation overall and/or an expansion in peatland extent. The potential for increased high-latitude peatland C accumulation is untested and unknown. Quantifying the relationship between recent past climate change and carbon accumulation is crucial to inform models that aim at capturing the response of the Arctic peatland C pool to future climate change. We aim to establish the relationship that climate change has with peatland i) net carbon balance (NCB) and ii) lateral expansion in the Arctic, with focus on two latitudinal transects in Northeastern Canada and the European Arctic. We will fit an ecosystem model to data from peat cores to estimate long-term NCB across multiple sites on our transects. In modelling NCB, we aim to tackle the well-established issue of incomplete decomposition towards the peatland surface associated with using apparent carbon accumulation rate (ACAR) as a metric for recent carbon accumulation history. To assess rates of lateral expansion, we will date peat initiation along transects perpendicular to the margins of existing peatlands. The topography of these transects will be informed by high-resolution contemporary drone data. This work is complemented with a remote sensing study focussing on the same regional transects.

Anthropocene ecological environment changes in high-latitude wetlands of Amur River Basin wetlands

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The high-latitude wetlands are quite sensitive to the projected global warming and increased anthropogenic impacts, and are gradually subjected to the hydrological ecological functions' degradation. Therefore, three peat cores were collected from three high-latitude wetlands that they are Tuqiang, Youhao and Honghe wetlands located in the upper, middle and lower streams of Amur River Basin (ARB) in northeast China. These peat cores were dated by 210Pb and 137Cs method. Multi-proxy analysis (Testate amoebae, black carbon and element contents) was used to reconstruct the water level and environmental changes in Amur River Basin wetlands during Anthropocene. The response of Amur River Basin to anthropogenic and climatic disturbances, and the possible affecting factors were also discussed. The results showed that: in the early Anthropocene (approximately AD1915), the wetland habitat was relatively humid and the Testate amoebae were dominant with the "humid" species. After that the variations of wetland water levels showed significant difference in the upper, middle and lower streams, while the regional climate remains the dominant factor. Since 1990, there was an increasing anthropogenic impact on the water table change throughout the Amur River Basin wetlands. The depth to water table gradually decreased throughout the Amur River Basin wetlands, and the dominant species of the Testate amoebae were *Phryganella acrospodia, Assulina muscorum* and *Assulina seminulum*. Thas was mainly due to the increasing anthropogenic, such as agricultural excess irrigation. Therefore, the water table change in Amur River Basin wetlands was controlled by regional climate change and the human being's activities, and suggested a significant spatial difference in the upper, middle and lowers streams in the past century.

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Paleoenvironmental histories over the past 81,000 years on the Jeju Strait shelf, off southwestern Korea, inferred from palynological records

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Palynological records from H-series cores (H-C05, 07, 11, 18, 26 and 27) has revealed changes in the depositional environment, vegetation, and climate of the southwestern Korean Peninsula since marine isotope stage (MIS) 5a. During MIS 5a (ca. 74–81 ka), the Jeju Strait shelf was an inner shelf with deposition influenced by the Jeju Warm Current (JWC), surrounded by land covered by mixed conifer and deciduous broadleaf forests under warm temperate conditions. The paleoenvironment during MIS 4 (57–71 ka) remains unknown due to a lack of palynomorphs from this stage. During mid–late MIS 3 (ca. 29–50 ka), the Jeju Strait shelf was an inner shelf influenced by cold-water masses from the Korean Coastal Current combined with weaker influences by the JWC, and the surrounding land was covered by mixed conifer and deciduous broadleaf forests that were less dense than in MIS 5a under warm and relatively dry conditions. A cold, slightly wet climate during MIS 2 (ca. 12–29 ka) led to the extension of predominantly cold-tolerant conifer forests due to lowstand sea levels, although inland East Asia remained cold and dry. During MIS 1 (ca. 0–12 ka), cold-tolerant conifer forests persisted into the early Holocene, and were subsequently replaced by mixed conifer and deciduous broadleaf forests as a warm climate was restored in the mid–late Holocene, when the depositional environment became an outer shelf due to highstand sea levels, as it remains today.

Indian monsoon variability in the Mahanadi Basin (IODP Exp. 353 Site U1445) during the last 200 ka

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The orbital-scale variability of the Indian summer monsoon (ISM) has been influenced by multiple factors, such as atmospheric CO_2 concentration, global ice volume, and insolation. Proxies for weathering activity and paleoproductivity provide potential insights into the driving forces of its variability. We documented multi-proxy data at IODP Site U1445, located in the Mahanadi Basin of the northwestern Bay of Bengal, to find out ISM variability over the last 200 ka. The proxy records, such as Nd/Sr isotopes of detrital particles, clay mineral compositions of the fine-grained sediments, biogenic opal and $CaCO_3$, organic carbon contents, and carbon isotopes of organic matter, represent that sediment sources, weathering patterns, and paleoproductivity were related to the ISM variability. Detrital Nd/Sr isotope data and clay mineral compositions suggest that the sediments at Site U1445 originated mainly from the Ganges, Brahmaputra, and Meghna rivers without dramatic provenance change between the glacial and interglacial periods. The weathering activity inferred from clay mineral compositions and the paleoproductivity shift reconstructed by biogenic opal and $CaCO_3$ contents suggest that the land-sea interactions were closely linked to the ISM precipitation between the glacial and interglacial periods. High precipitation by the strong ISM resulted in intense chemical weathering and dominant biogenic opal deposition during the interglacial periods. In contrast, low precipitation by the weak ISM led to reduced chemical weathering and predominant $CaCO_3$ deposition during the glacial periods. Further, the ISM variability driving the land-sea interactions in the Mahanadi Basin was modulated by the Indonesian throughflow.

Molecular and isotopic indicators of fire history, population, vegetation and climate change in the Maya lowlands

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Understanding past societal responses to climate change requires proxy indicators of human population, climate and land-use change. We apply a range of proxies to a lake sediment core from Laguna Itzan, a cenote adjacent to the ancient Maya population centre of Itzan, in order to examine the response of the lowland Maya to climatic and environmental change, which remains poorly understood. By combining molecular proxies for population (faecal stanols) and biomass burning (polycyclic aromatic hydrocarbons or PAHs) with isotopic analyses of plant wax n-alkanes as proxies for vegetation change (δ13C) and palaeohydrology (δ2H), we show the complex interplay of environmental and societal changes over 3300 years.

Faecal stanols suggest at least three periods of significant population decline associated with precipitation change, including between 3300 and 2900 cal yr BP and 1860-1670 cal yr BP, as well as the widely documented Terminal Classic drought (1220-1050 cal yr BP). The use of PAHs provides a record of fire history from both hearths as well as from vegetation burning associated with hypothesised slash and burn land clearance, or swidden, agriculture. Fire history can be linked with records of vegetation change inferred by δ13C of n-alkanes, which fluctuate between more negative values associated with forest (C3) vegetation and more positive values associated with maize (C4) agriculture. Our data indicate that human population dynamics and patterns of land clearance for agriculture varied substantially throughout the sediment core record, and that palaeoclimatic change may have largely driven these patterns.

Climate history and vegetation changes in southwest Morocco

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Southern Morocco is presently subject to severe droughts, desertification and land degradation, because of the development of socio-economic activity and climate variability, which has provoked severe changes in the main natural forest ecosystems. In this study, we used palynological data from two high-resolution marine sediments cores collected off offshore Agadir in southwest Morocco in combination with published high-resolution stable isotopes ($\delta^{18}O$ and $\delta^{13}C$) from speleothem records, in order to evaluate the impact of past climate changes on the vegetation in southern Morocco. The results show that the rapid increase of population in southern Morocco caused land and vegetation degradation due to the expansion of pastoralism and agriculture with the good presentation of *Argania spinosa*, Cichorioideae and Asteroideae pollen, especially at the beginning of the Arab invasion of North Africa (700 CE), with the modest representation of deciduous oak. Increasingly arid conditions in Morocco after 619 to 940 CE are possibly related to NAO+ conditions. A long period of dry conditions in Medieval Climate Anomaly (MCA), with the short humid period, showed by the still quite high percentages of non-arboreal pollen with a significant expansion of Asteroideae, Cichorioideae and CCA. The Little Ice Age (LIA) was characterized by a recovery to wetter conditions, remarked by the decrease of Argania spinosa, Asteroideae and Cichorioideae pollen and an increase of *Cedrus atlantica*, *Juniperus* and *Pinus*. Therefore, the hydroclimate conditions in Morocco continued to be more humid until 1970 CE.

East Asian winter monsoon variability during middle to Late Holocene on Jeju Island, South Korea

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Understanding the East Asian monsoon is necessary because society, culture, and the environment have been affected by climate change. To date, the change in the East Asian winter monsoon (EAWM) and its controlling factors is still unclear in downwind areas that experience the Siberian High, mostly due to the lack of a high-resolution EAWM index. Based on the correlation between diatom variations in a volcanic cone of Jeju Island, South Korea, with past regional climate changes such as temperature, dust, sea ice, and solar activity, in this study, we evaluated the changes in the climate from the sum of acidophilous species (SAS), known to be mainly controlled by the pH of the prevalent water pool, and inferred that the SAS increased during the cold and dry periods (e.g., Little Ice Age and Dark Age Cold Period). In addition, millennial-timescale fluctuation in the detrended SAS during the past 8000 years, with peaks at ~500, 1500, 3000, 5600, 6600, and 7600 cal yr B·P., corresponded to the ice-rafted events reported from studies conducted on subpolar ocean sediments and solar activity. In this study, we suggest that, historically, high-latitude climate change driven by solar activity has controlled the EAWM; additionally, we present the application of the SAS in Jeju Island as a high-resolution EAWM index.

Anomalous pollen evidence at the mouth of Ría de Vigo reveals new details about the Holocene marine transgression in NW Iberia

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A high-resolution pollen record from the upper 155 cm of the MVR-3 vibracore (recovered at 30 m bsl in the outer sector of Ría de Vigo, NW Iberia) reveals noticeable sedimentation changes during the last 12,000 cal yr BP. A reliable age model was built using part of the 14 AMS radiocarbon dates available, namely 3 marine shells and 11 pollen residue samples extracted from muddy sediment. Deciduous *Quercus* pollen expanded during c. 9700-8500 cal yr BP at the beginning of the RSL rise. Subsequently, two *Pinus* pollen peaks (40-60%) are recorded between 138-115 and 98-73 cm depth separated by a *Quercus* maximum dated between 7800-6000 cal yr BP. The total accumulation rates of palynomorphs decline during both *Pinus* peaks, while *Lingulodinium machaerophorum* (characteristic of well-stratified estuarine waters) notably decays and other dinoflagellates (*Bitectatodinium tepikiense* and *Spiniferites* spp.) increase revealing enhanced mixing of coastal waters. Moreover, in spite of the suitable radiocarbon ages obtained from pollen extracts at the stage dominated by *Quercus* and also after the beginning of the regional deforestation, the ages obtained from the anomalous *Pinus* peaks seem inverted and notably aged. These apparently jumbled data may be a coherent high-resolution record describing the main sedimentary processes that occurred during the marine transgression, and it allows to improve the interpretation of the seismic evidence (units, unconformities) previously described. In Ría de Vigo, the transgressive system tract (TST) includes deposits accumulated from the onset of coastal transgression (<12 kyr BP) until the time of maximum transgression (i.e. the *Quercus* maximum dated between 7.8-6.0 kyr BP, which corresponds to the Holocene *Climatic Optimum*). The basal boundary of the Holocene sequence corresponding to the first *Pinus* peak is an erosional surface associated with marine transgression, i.e. a ravinement surface, with coarse sand or bioclastic gravel facies typical of high-energy environments. The Holocene unit below it is therefore interpreted as the first transgressive system tract (TST1) during the pulse of relative sea-level rise after the YD. The second Holocene unit, also with an erosional basal surface, i.e. the second *Pinus* peak, would correspond to a second phase of RSL rise (TST2).

Pollen sedimentation in fluvio-marine systems: a comparison between modern pollen evidence in sea-floor, coastal lagoons and upland ponds from Ría de Vigo, NW Iberia

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To determine whether modern pollen content from 1) marine, 2) coastal lagoon, and 3) upland lake sediments reflects the factual regional and extra-local vegetation composition, we analysed modern samples at the same main fluvio-marine basin (Ría de Vigo, NW Iberia). Aspects such as basin size and morphology, relative position in the catchment, local vegetation, canopy configuration and seasonality of the water table were considered. Our results suggest that the average pollen percentages of all upland pond sediment samples studied allows a fairly good reconstruction of the main vegetation units in the area. Still, major differences between the average samples obtained in each sedimentary system and also between some samples taken from the same system are found. The main factors explaining those differences are the size of the pond, its tree canopy and the seasonality of the water table, which strongly determines the Ericaceae and *Pinus* percentages. Anomalous *Pinus* pollen peaks occur in dry periods when the water table remains low, and sediment can also be depleted of some high-buoyancy pollen types (tetrads and saccate) when the water level is high and effluents are active. Samples taken in the semi-closed coastal lagoon-beach complex at the Cíes Islands suggest that *Pinus* pollen abundance increases in the intertidal flats samples with respect to those taken in the subtidal zone of the lagoon. Besides, the *Pinus* pollen concentrations in both the intertidal and subtidal samples at the lagoon are significantly lower than *Pinus* pollen concentrations found in other full-marine subtidal sediments recovered along the main axis of the ria. On the other hand, there is currently no local heathland on the islands, nor was there throughout the 20th century, and the closest heaths in the continent are more than 5 km distant. Nevertheless, we have found *Erica* pollen evidence inside the lagoon of Cíes Islands. Its spatial distribution seems to be preferentially related to the western connection between the lagoon and the ocean that allows water exchange throughout the tidal cycle. Thus, the new pollen data can confirm the preferential ability of tetrads to be long-distant transported by sea-water currents.

Holocene alpine vegetation, fire, and climatic dynamics of central Taiwan

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Due to the frequent tectonic activity and high erosion rate, a lake or pond with sediments covering whole Holocene records is rare in Taiwan. Tien Pond (TP) of the Xueshan Range is a small pond at 2620 m in central Taiwan. A 250-cm length sediment core (DXS-TP) was taken in the TP in 2017. Based on the results of 14 radiocarbon dates, it covered the records during the last 8400 cal BP. The continuous data of pollen and macro-charcoal from a sediment core from TP to reconstruct the changes in Holocene vegetation, fire frequency, and climate under multidecadal resolution. The deposition hiatus during 6400-3600 cal BP may correlate to the 4.2 ka event or the change in local hydrological condition. The reconstruction of biome types in TP was simulated by using the biome model BIOME. The results of biome reconstruction reveal the consistent temperate forest during the Holocene in western alpine Taiwan. The paleo-temperature was inferred by the ratio of upper montane forest and montane forest pollen (UMF/MF) and principle component analysis axis two (PC2) and indicated two cool periods during the early Holocene and the Little Ice Age. The paleo-precipitating inferred by Cyperaceae pollen and macro-charcoal concentration showed relatively dry periods during the early Holocene and 3600-2000 cal BP. The study area's climatic condition was similar to the East Asian Monsoon pattern during the Holocene in Taiwan.

Holocene climate variability recorded in central Mexican lacustrine archives

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Central Mexico represents a highly sensitive area for the study of Holocene climate variability as it lies beyond the northern limit of the Intertropical Convergence Zone and in the southern part of the North American monsoon domain. The HolMeCl project combines the acquisition and analysis of short and long sedimentary sequences retrieved from seven crater lakes spanning the Trans Mexican Volcanic Belt (TMVB). The TMVB represents widespread closed-system crater lakes whose sedimentary sequences are unique archives of past climate variability. Age-depth models will be constrained by a combination of geochronology (^{137}Cs, ^{210}Pb, and ^{14}C), tephrostratigraphy and varve counting (when present). To explore past hydrological and environmental changes, the sediments will be subjected to detailed multiproxy analyses using a spectrum of mineralogical, geochemical (δ^{13}C and δD signatures of *n*-alkanes leaf-wax and elemental compositions) and paleobiological (diatoms and pollen) indices. The youngest sections of the sedimentary sequences will be precisely dated to estimate the temporal resolution of sedimentation rates, allowing us to validate the signals that individual proxy data represent through comparing them with the local meteorological data. Using the validated proxies, the long sedimentary sequences will be interpreted in terms of past climate reorganizations particularly paleo-ENSO variability. Comparison of these new precisely-dated long sequences with the existing paleo-ENSO records for the tropics would bring a more global picture of ENSO variability over the Holocene at decadal or sub-decadal resolution, if the sedimentary records are annually laminated.

Human impact leads to unexpected late Holocene reoligotrophication of a Swiss mountain lake

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Early human impact on lakes has in many cases been reported to lead to nutrient release, increased algal productivity and eutrophication, as well as depleted deepwater oxygen concentrations. For Central Europe, and particularly the Alpine region, many records are now available that document early, human-induced eutrophication influencing lake ecosystems as early as the Neolithic, Bronze age, Roman and Medieval periods. Here we report the unexpected and contrasting finding of a pronounced oligotrophication trend in a Swiss mountain lake due to human activities during the Medieval times. A sediment core from Lac de Champex (1,466 m asl in the Valais, Switzerland) was analysed for fossil chironomid and other aquatic invertebrate remains. Chironomid assemblages in most of the record show pronounced changes that agree with the known climatic development during the early and mid-Holocene and a progressively stronger influence of peat development around the lake, resulting in an assemblage with low chironomid accumulations dominated by *Procladius* with high concentrations of *Chaoborus* around 2,000-3,000 cal. BP. In the latest part of the record, at around 1000 cal. BP, a pronounced and abrupt increase in sediment accumulation rates and chironomid influx was observed during a period with clear evidence for local human activities (e.g. pollen of pasturing-indicating taxa and cereals, dung spores). Some changes in chironomid and invertebrate abundances were also apparent at this depth followed by a major transition in the chironomid and invertebrate assemblage around 500 cal. BP, with the disappearance of *Chaoborus*, a decrease in *Procladius*, and the increase or new appearance of a range of chironomids including several stream inhabiting taxa. Numerical and palaeoecological analysis of the results confirmed that these changes were towards assemblages characteristic for more oligotrophic, oxygen-rich conditions. We conclude that late Holocene human impact on Lac de Champex and its surroundings resulted in a pronounced re-oligotrophication of the lake, possibly promoted by increased erosion from the Medieval period onwards but from 500 cal. BP very likely due to the building of an irrigation canal (bisse), leading to the inflow of clear, cool water and changing the hydrological characteristics of the lake.

Vegetation and climate dynamics in central Mexico during the past millennium recorded in a sediment core from Lake Teremendo

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Central Mexico is influenced by multiple atmospheric circulation systems including the Intertropical Convergence Zone (ITCZ), the North American monsoon, and polar fronts, making it highly sensitive to climate change. Variations in the position and strength of these atmospheric systems result in significant changes in the terrestrial and aquatic ecosystems of central Mexico. The past millennium, characterized by warm and cold climate perturbations, namely, the Medieval Warm Period (MWP) and the Little Ice Age (LIA), provides a unique time interval to explore environmental responses to the anomalously warm and cold periods. Here, we present a multiproxy record including pollen, elemental geochemistry, loss on ignition, grain size, and magnetic susceptibility (MS) of sediment cores retrieved from Teremendo, a crater lake in central Mexico, spanning the last millennium. The dominance of temperate vegetation, particularly pine forests, at the expense of tropical plants around the fourteenth to nineteenth centuries suggests a decline in temperature and summer rainfall. The laminated sediments of this interval, which display the greatest variations in elemental abundances and MS in the record, hint at unstable climatic conditions with amplified seasonality during the LIA. Around AD 1910, the pollen and sediment indices suggest a transition from the LIA to the recent warm period, where a decline in pine forests coincides with an increase in tropical vegetation, and the weakly laminated sediments show smaller variations in elemental abundances and MS. Such observation suggests a rise in temperature and summer rainfall and more stable climatic conditions since AD 1910. Land use change related to the Mexican Revolution in the early 20th century may have contributed to the vegetation changes, however, evidence from other central Mexican records supports climate-driven vegetation dynamics. Thus, our results suggest that a southward displacement of the mean position of the ITCZ during the LIA was accompanied by reduced summer rainfall and increased polar front incursions over central Mexico in the winter. Given the great potential of the Teremendo lacustrine archive, we will extend our time interval beyond the last millennium by investigating an already retrieved long sediment core from the lake covering the entire Holocene epoch.

Towards a better understanding of lake ecosystem response to natural climate variability – a study of Lake Bright, New Zealand

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The impacts of environmental and climate change on freshwater ecosystems are typically a combination of natural processes and human alteration (e.g. land-use changes). The arrival of humans to New Zealand about 750 years ago is known to have impacted landscapes and makes it difficult to study natural conditions that are undisturbed by human activities over timescales that are relevant for paleoclimatic reconstructions. However, remote, alpine lakes are thought to record environmental and climate changes independent of human impact in the Southwest Pacific.

For this study, we investigate sediment cores obtained from a remote alpine lake in Fiordland National Park on New Zealand's South Island. A 1.6 m long sediment core was recovered from the center of Lake Bright at a depth of 19.5 m in September 2019. In our multiproxy approach, we used bulk organic C and N stable isotopes, lipid biomarker concentrations and high-resolution X-ray fluorescence and hyperspectral imaging to study lake productivity, sources and provenance of clastic and organic matter, as well as changes in water quality and vegetation composition.

The Lake Bright pollen stratigraphy does not show any evidence of recent human-induced landscape change in the surrounding catchment. A largely stable vegetation community composed of forest and grassland pollen spans the last 4 kyrs of the record with a very low abundance of microscopic charcoal and exotic plant pollen in the uppermost part of the stratigraphy, which is likely sourced from lowland locations. Initial biomarker data confirms that the greatest proportion of organic matter is derived from vascular plants from the lake catchment and low contributions of aquatic organic matter sources. Non-destructive XRF and hyperspectral scans of the core indicate variations in algal productivity, while a trend to more reducing conditions is observed in the uppermost portion of the record. We will discuss these findings, along with results from a stable C and N isotope stratigraphy, biogenic silica concentrations, and organic geochemical reconstructions of air temperature and precipitation, to deconvolve changes in organic matter provenance and to better understand how climate changes affect remote alpine lake ecosystems, independent of human impact.

Summer temperatures during the Holocene inferred from a chironomid record from Sierra Nevada, southern Spain

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Accurate and continuous quantitative paleotemperature records from the past are rare in southern Iberia, mostly due to the scarcity of continuous sedimentary sequences in terrestrial environments from that area. In this study we show the first Holocene mean July air temperature reconstruction based on fossil chironomids from a sedimentary sequence obtained from Laguna de Río Seco, an alpine lake in Sierra Nevada, southern Spain. Reconstructed summer temperatures agree with changes in summer insolation and other palaeotemperature records from alpine environments from southern Europe and show the Holocene thermal maximum between 10 to 8.0 ka (1 ka = 1000 cal yr BP). Rapid cooling occurred after the warmest maximum and between ~8.0-7.0 ka and temperatures stabilized between ~6.5 and 3.0 ka. A further cooling trend started ~3.0 ka, and coldest summer conditions were reached at 1.4 ka (~550 CE) and ~0.2 ka (~1750 CE), coinciding with the Dark Ages and Little Ice Age, respectively. This record also shows relatively warmer summer temperature conditions during the Iberian-Roman Humid Period ~2.0 ka and during the Medieval Climate Anomaly at ~0.9 ka. Summer climate warming of more than two degree Celsius is observed in the last decades showing that recent warming is amplified in high alpine environments.

Distribution of long-chain diols in the Baltic Sea and its application in paleoenvironmental reconstruction

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Long-chain diols (LCDs) are lipids produced by microalgae and occur widely in lakes, rivers and marine environments. A series of proxies based on the distribution of LCDs in the sea has been widely used to reconstruct the paleoenvironment. However, the LCDs' distribution and its related environmental proxies in brackish water environments are not well studied. In this study, we investigated the occurrence and distribution of LCDs in surface sediments and one sediment core from the Baltic Sea, and explore the relationship between their distributions and environmental factors including salinity, nutrient concentrations and sea surface temperature.

The surface sediments from the Gulf of Bothnia, the Gulf of Finland and the Baltic proper are dominated by the C_{32} 1,15-diol with a relative abundance between 38% and 75%, and it decreases towards the North Sea. Additionally, the relative abundance of C_{30} 1,15-diol which the Diol index, a salinity proxy, is based on does not correlate with salinity in the Baltic Sea. However, the relative abundances of C_{28} 1,13-, C_{30} 1,13- and C_{32} 1,15-diol correlate with salinity. Based on this, we propose a new salinity index that expresses the abundance of C_{28} 1,13-diol relative to C_{28} 1,13-, C_{30} 1,13-and C_{32} 1,15-diol. The new salinity index shows a strong positive correlation with the sea surface salinity (r^2=0.7594, p<0.001).

In the sediment core from a fjord-like inlet to the Baltic Sea located on the southeast coast of Sweden, the salinity index proposed in this study indicates decreasing salinity over the last 5500 years, which is in concert with the relative sea level decreasing due to isostatic rebound. Considering that freshwater from river runoff can be a major driver at the location near the river mouth, the salinity index could potentially reflect changes in riverine organic matter input after the coast stabilized. However, both the BIT index, a proxy for soil organic matter, and the C/N ratio suggest an increase in the terrestrial organic matter input responding to farmland expansion over the last 600 years, but no change is observed in the riverine input indicated by our new proxy.

Seasonal hydroclimate in the North Sea-Baltic Sea region during the Last Interglacial

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The Last Interglacial (LIG) experienced substantial changes in seasonal insolation compared to the present day. The higher-than-present seasonality in insolation could have led to changes in hydrography and water mass exchange in the North Sea and Baltic Sea region. Here we investigate the influence of solar radiation and greenhouse gas (GHG) forcing on the regional climate, using both model simulations of LIG (127 ka BP) and the present day (PD, 1990 CE) and the reconstructions of seasonal water conditions based on benthic foraminifera and geochemistry data. The differences between the anomalies of LIG-PD and LIG-pre-industrial (PI, 1850 CE, control experiment) reflect the effect of greenhouse gas concentration. The simulated LIG conditions in the Baltic Sea region (including the Kattegat and the Danish Straits) show more saline and colder bottom waters than those in PD, which agrees with the reconstruction data from the investigated sites. The LIG sea surface temperature (SST) is lower in spring and higher in summer than those for PD conditions. The thermocline is stronger during the summer months in LIG due to the higher SST and lower bottom water temperature (BWT) compared to PD. Together it indicates that the Baltic LIG SST is highly influenced by the insolation factor whereas the PD BWT of the Baltic Sea is affected by North Sea input of warmer seawater into the southern Baltic, cause by increased GHG-forcing.. The simulated LIG surface water salinity suggests that during the winter months, the western Baltic is to a large degree affected by the North Atlantic Oscillation (NAO) and an associated larger influx of more saline North Atlantic water. Further, the temperature anomalies (LIG-PD) show significant inverse correlations with the precipitation-minus-evaporation (P-E) in the Baltic Sea entrance. However, the P-E balance may have minor effect in changing the salinity in the North Sea-Baltic Sea and the open sea area. Our study investigates the interaction and correlations of regional seawater temperature and salinity with internal variability (P-E and NAO) under different external forcing.

Postglacial landscape dynamics and fire regimes from Central Patagonia, Chile (44°S, 72°W): Evidence from Lago Las Mellizas.

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In central Patagonia (~44°S) palynological records from the eastern forest-steppe ecotone indicate substantive changes in vegetation cover after the LGM, coupled with high fire activity during the Early Holocene and at c. ~3000 cal. yr BP, the latter likely associated with prehistorical human occupation. However, there has been a lack of paleoenvironmental evidence for vegetation changes and fire activity within the rainforest in this area. Here, we present the reconstruction of past vegetation and fire activity for the last 13,700 cal yr BP at the wetter western margin of the forest-steppe transition obtained from a lacustrine sediment core from Lago Las Mellizas (LLM). (44°S, 72°W) located at the margin of the Cisnes River in the Aysén region, Chilean Patagonia. This area has also been the focus of an archaeological study. The LLM record indicates low fire activity (2 fires 1000 $yr^{-1)}$ between 12,500 and 10,500 cal yr BP; negligible fires during the Middle Holocene, and a maximum peak in fire magnitude at ~300 cal yr BP, likely associated with the beginning of the Chilean occupation and settlement in the region. After 12,200 cal. yr BP pollen concentrations increased substantially, likely reflecting a lowering in the Cisnes River elevation and isolation of LLM. After c. 10,000 cal yr BP the development of evergreen forest is most notable with the presence of the evergreen species *Podocarpus nubigenus* and Cupressaceae, probably *Pilgerodendrum uviferum*. A more open forest developed during the Middle Holocene, as indicated by the increase of Poaceae percentages from 5,300 cal yr BP. Vegetation changes associated with human activity are not identified and multivariate analyses indicate no association between fire parameters and vegetation changes. Therefore, we conclude that changes in landscape dynamic at the western margin of the Aysén region are directly controlled by climate, associated with latitudinal shifts of the Southern Westerlies Winds throughout the Holocene.

Changes in sediment distribution on the eastern continental margin of Korea since the LGM

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We analyzed surface sediments collected from the southeastern continental shelf of the Korean Peninsula below a water depth of 500 m for grain size, organic carbon, and geochemical elements. The surface sediments divided into four groups based on the chemical compositions: outer continental shelf, inner continental shelf, Korea Strait Shelf Mud (KSSM), Hupo Basin. Outer continental shelf sediments were composed mostly of coarse-grained sediments that seemed to have been deposited during the glacial age and remained in place due to morphological features since the LGM. Whereas, KSSM and Hupo Basin sediments were composed mostly of fine-grained sediments and developed along the coastline on the inner shelf area. KSSM sediments were deposited with mixed sediment from Chinese and Korean rivers since the LGM. Sediments in the Hupo Basin have geochemical characteristics indicating different sources from those of KSSM sediments. Considering with the seismic results and morphology comprehensively, the fine-grained sediments on the Hupo Basin supplied from nearby rivers beside on the Hupo Basin

Hydroclimatic fluctuations over the Holocene in southern Iberia (Sierra Nevada, Spain) disentangled by fossil cladocerans

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Laguna de Río Seco is a pristine alpine lake situated in the massif of Sierra Nevada, which is the most important mountain range in southwestern Europe and a region of extraordinary sensitivity to climate change. Here we analysed cladoceran subfossils in the Laguna de Río Seco sedimentary record covering the Holocene to investigate the faunal responses to environmental variables and to obtain new insight into past climate variability in the study region. In addition, we applied mean body size and abundance of fossil ephippia as supplementary proxies for paleoclimatic interpretations. Multivariate techniques showed that the main drivers controlling the biological assemblages were factors related to hydroclimatic parameters, deduced by the abundance of aquatic vegetation and the C/N ratio. Two different biological assemblages were described depending on the millennial-scale variations of lake level. A higher lake-level assemblage was composed of *C.sphaericus* and *A.rustica* and a low lake-level assemblage was characterised by *C.elegans*. The Early and Middle Holocene (ca. 10500 to 5500 cal yr BP) was relatively humid, with two different periods separated by a small decline in precipitation ca. 8000 cal yr BP. At ca. 5500 cal BP, there was a clear shift towards lower lake levels and thus, drier conditions. This is inferred by the increase of species that thrives well in shallow ecosystems, such as *C.elegans*. The Late Holocene is characterised by continuous changes in lake level within a trend towards hydrological aridification, which is interrupted by a positive peak in precipitation around the Iberian-Roman Humid period.

Late Holocene paleoenvironmental changes in north-eastern Germany derived from a high-resolution lacustrine record from Schweriner See

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Lacustrine deposits provide excellent archives to investigate past environmental variability. Schweriner See (See = lake) is the fourth largest lake in Germany (61.54 km²), and the second largest in NE-Germany. Because of its location, it constitutes great value for paleoenvironmental reconstructions, since in such a large system natural supraregional paleoenvironmental signals are not overprinted by single events. The lake was formed after the Last Glacial Maximum and is located ca. 20 km away from the Baltic Sea within the transitional zone from maritime to subcontinental climate hence making it very susceptible to environmental variations occurring within NE-Germany.

Schweriner See is a carbonate-rich, lowland lake (38 m a.s.l.) characterized by a complex bathymetry with several deep spots, channel structures and an extended littoral shallow water area. Due to this morphology, we coupled investigations on surface sediment samples to better understand internal lake dynamics, short gravity sediment cores (max. 1 m length) and an 18 m parallel cored sediment records from the deepest spot (52 m water depth). All samples were analysed using a multi-proxy approach of (hyper-)spectral, sedimentological (e.g., grain size distribution) and geochemical (e.g., CNS, XRF core scanning) methods. To record the general transitions within the lake and catchment, we additionally used a diatom-based trophic and a pollen-based vegetation reconstruction. The chronology of the long sequence is based on a multi-dating approach including radiocarbon (only terrestrial macro-remains) and $^{210}Pb/^{137}Cs$ ages. Currently, only the upper part of the 18 m long sediment record possesses robust chronology, that is 12 ^{14}C dates per 10 m with a maximum age of $3300^{+130}/_{-130}$ cal. BP. This section reveals a high sedimentation rate of ca. 0.3 cm a^{-1} for the Late Holocene highling its suitability to infer natural past environmental changes in high-resolution. Anthropogenic impact is visible in all gravity cores recovered from Schweriner See indicated by an increase in eutrophication and heavy metal contamination since the Industrial Revolution around 1850 and peaks shortly before the German reunification in AD 1989.

Dynamics of planktonic foraminifera population in the Arabian Sea during the last climatic cycle.

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Planktonic foraminifera are calcite shell organisms, which are widely used in paleoceanographical studies to reconstruct climate variables (for example ocean temperatures). For that purpose, the composition of planktonic foraminifera assemblages is determined in samples from marine sedimentary cores from various oceanic provinces in order to reconstruct species related distributions both along time and space. Based on nearly one century of acquisitions of this kind of data, some species have been identified as good tools to determine hydrographical parameters like productivity or as relevant to stratigraphy. However, these data are rarely used to quantify the intraspecific dynamics of the population, particularly during extreme time periods as glacial/interglacial flips. The purpose of this on-going work is to study the dynamics of each species as well as one relative to another.

In this study, we propose to use descriptive statistics on various assemblages from the Arabian Sea to reconstruct the population structure and its variation during the last climatic cycle in an area under the influence of monsoon and characterized by the seasonal development of large upwelling systems. Multivariable analyses allow us to connect some species abundances and to observe how their similarity or dissimilarity evolved during contrasted climatic periods. These results coupled with ecological knowledges provide a way to improve the reconstruction of paleoenvironmental signals.

Paleolimnological changes in an alpine lake during the Holocene inferred from a diatom record from Laguna de Río Seco, Sierra Nevada (Southern Spain)

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High-mountain ecosystems of the southern Iberian Peninsula are among the most vulnerable and the first to respond to modern climate change in southwestern Europe. Our main aim is to identify the changes in the diatom communities in the last ~12500 years to assess the ecosystem responses to climate change over time. A composite sedimentary record consisting of a long (LdRS,150 cm) and a short sediment core (SdRS, 16 cm) were retrieved at the deepest part of Río Seco Lake, an alpine lake at 3020 m a.s.l. in the Sierra Nevada National Park. A chronology for the past ~12500 years for LdRSand ~200 years for SdRS was stablished. Both cores were analyzed with a high temporal resolution (intervals of 0.25 and 1 cm) and a minimum of 300 diatom valves were counted for each sample. Diatom assemblage was dominated by small benthic fragilarioid taxa like *Staurosira venter* and tichoplanktonic species like *Aulacoseira alpigena*. The greatest compositional changes occurred at approximately 7200, 5000 and 2800 cal yr BP. Relatively low abundance of epiphytic, tichoplanktonic and other planktonic species indicates aridity, drying of catchment meadows and reduced water level and turbulence, linked to warm and dry climate between 10000 to 7200 cal yr BP. This warm period with low lake water levels, was followed by a long cooling trend between 7200 and 2800 yr BP in which tichoplanktonic species as *A. alpigena* are dominant, as our results highlight. Two steps were observed in this cool period: period between 7200-5000 yr BP, with small compositional changes, and the period between 5000 and 2800 yr BP with a noteworthy increase in the abundance of *A. alpigena* indicating high lake water level, and fragilaroid taxa such as *Fragilaria gracilis*. In the period between 2800 and 300 yr BP tichoplanktonic species decreased and small fragilariacean and alkaliphilous species increased but with several peaks of reverting conditions. SdRS core suggests a more pronounced tendency to alkalinization, catchment aridity and low water level, probably related to present climate warming.

Holocene climatic and environmental changes in the Yangtze River Delta

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The delta is located at the land-ocean interface and an ideal location to study climate and environmental changes. However, complex sedimentary environment hinders the establishment of a reliable chronostratigraphy for the area, which in turn impact the research process of environmental evolution on geologic time scales. In this study, optically stimulated luminescence (OSL) dating technique and geochemistry are used to study Holocene climatic and environmental changes in the Yangtze River Delta region.

One sediment core was drilled from Hengsha Island of the Yangtze River Delta to depth of 40 m. A total of 16 OSL samples were collected from the cores. Single-aliquot and single-grain quartz were used to determine the sediment ages. The results showed that there are two sedimentary hiatuses at ~15 m and ~34 m core depth, and the core is divided into three sections: (i) the upper 15 m of the sediment was deposited about 0.4 ka years ago; (ii) deposition is continuous from 1.5 to 5 ka in thickness from 15 to 34 m; (iii) the deposition time at the depth of 34–40 m is ~10–11 ka. On the basis of chronology, sampling at 2–20 cm intervals was used for geochemistry analysis, which is currently underway. Finally, we will discuss the similarities and differences of the Holocene Asian monsoon reflected by the estuarine records, stalagmite and lake records in the Yangtze catchment.

Climate oscillations during the transition MIS 6-5e against MIS 2-1, based on data from Central Europe

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Hundreds of the Eemian Interglacial sites are documented in Central Europe, therefore the Eemian pollen succession is quite easily recognizable and its regional characteristics are widely identified. By contrast, records of the Late Saalian, including a continuous transition to the Eemian Interglacial, are relatively rare and mostly short. Nevertheless, decline of the Late Saalian is recorded as the stadial-interstadial oscillations at many sites in the northern continental Europe. The Late Glacial sites that comprise a transition to the Holocene (MIS 2-1) are also numerous in this area. However, only a few of them possess a full record of the vegetation development throughout this period and most of the succession contains gaps or local disturbances. Most data that document these periods come from shallow lakes of different origin and the most complete sequences are usually derived from annually laminated sediments. Based on numerous data from the terrestrial sites in Poland, Ukraine, Belarus and Western Europe, similarities and differences of climate fluctuations during the Late Saalian/Eemian and the Late Glacial/Holocene were identified. The general climatic improvement during the Late Saalian, expressed in the pollen record, reflects two oscillations that were reported in Western Europe – the older cooler stadial and the younger warmer oscillation Zeifen-Kattegat. In some aspects, these oscillations can be compared to the decline of the Late Glacial during the Weichselian. The general trend of the vegetation transformation is clearly similar: from open communities in a cold period to boreal plant communities in a warmer one. The example of the Late Saalian “Parchliny 2016” section in Central Poland shows that the pollen succession of the Late Saalian is similar to the pollen record of the Late Weichselian. In addition, results of the analysis of the terrestrial data are found to be reflected in oxygen isotope curves from the North Atlantic deep-sea cores.
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Lipid biomarkers of marine phytoplankton variability in modern snow and marine sediments from the southwestern Ross Sea, Antarctica

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Phytoplankton play an essential role in ocean-atmosphere systems by forming the base of the marine food web and are crucial to the global carbon cycle, acting as a significant carbon sink. The Ross Sea, Antarctica has high primary production rates influencing atmospheric carbon dioxide drawdown into the ocean. However, our understanding of how phytoplankton in the Ross Sea may respond to future climate change is limited by short observational records.

Molecular fossils (lipid biomarkers) of phytoplankton can extend observational records of primary production. Biomarkers are found in snow and marine sediment samples providing a unique opportunity to compare across archives. Here we present new results of lipid biomarkers in Ross Sea paleoclimate archives: a spatial array of snow/ice samples and marine core tops from McMurdo Sound to Terra Nova Bay, as well as filtered Ross Sea ocean water. We have investigated the spatial variability of phytoplankton biomarker concentration and composition across the different archives. Results from all three archives demonstrate the presence of phytoplankton biomarkers in the southwestern Ross Sea. The multi-archive comparison will provide new information relating to the spatial distribution and community composition of primary production in the Ross Sea and how concentrations of biomarkers relate to primary production rates. Overall, it will help validate biomarkers as a proxy to interpret longer palaeobiology records in Antarctica and help inform the impact climate change might have on biodiversity and the global climate system.

Geochemical evidence for an increased primary productivity during the Bölling-Alleröd Interstadial period than the Holocene along the south-western continental margin of India

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The south-western continental margin of India (SWCMI) is one of high primary productivity (PP) regions in the Northern Indian Ocean (NIO) owing to the dominance south-west monsoon winds (S-W MW) during the summer monsoon, followed by north-east winds during the winter monsoon. The decreased PP during the glacial conditions attributed to the weakened S-W MW, however, this study shows that the S-W MW seems to have been increased during the interstadial conditions, particularly during the Bølling–Allerød (B-A) period than the Holocene. Geochemistry of a radiocarbon dated sediment core from SWCMI at 1400 m depth around 13^{o} N latitude indicates that the PP indicator elements, such as Zn and Ni show contrasting behaviour from late-Glacial to the Holocene period. The Al-normalized Zn and Ni data of the core studied show an inverse trend particularly during the B-A period and to some extend during the mid –Holocene. Further, Al-normalized Zn ratios to Al-normalized Ni ratios are nearly two-fold higher during the B-A, than the entire core, particularly the Holocene section. This suggests that the diatom productivity was much higher during the B-A period relative to the Holocene time span. This finding is in agreement with the increased rainfall inferred from speleothems over the terrestrial regions of the Indian sub-continent, and decreased salinity, enhanced PP and increased denitrification rate noticed in the continental marine realm surrounding the India during the B-A period. Although many trace elements required for primary productivity, the biochemical/metabolic reactions of a cell and uptake of carbon by the phytoplankton, the most preferred trace element is Zn rather than Ni. Henceforth, Zn and Ni in marine sediments, particularly in the pristine continental margin can be used as proxies to delineate paleo-primary productivity variations. The utility of the trace elements suggested here is in agreement with the similar trace elemental isotopic investigation made by the GEOTRACES group in the productive upwelling regions.

Interplay between climate, ecosystem development, and evolution of biodiversity in Lake Victoria, East Africa

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Analysis of long-term climatic variability is critical for examining the intrinsic dependency of natural ecosystems and biodiversity on climate. The transition from the last glacial episodes of the Late Pleistocene to the dawn of the Holocene epoch led to major changes in climatic conditions that have had profound impacts on the landscape. Within East Africa, Lake Victoria is located across the boundary of two major climate zones: the precipitation-rich central African upland and the semi-arid east African plateau. Due to its shallow depth in relation to surface area (~68,800 km2), Lake Victoria is particularly sensitive to changing climatic conditions, and since its inception ~400ka, the lake has undergone multiple episodes of drying and filling coinciding with the glacial-interglacial cycles. Previous paleolimnological research shows the most recent refilling of Lake Victoria following the Last Glacial Maximum, occurred after desiccation events reported between ~18 and ~15 ka BP. Within this relatively short geologic history, the endemic adaptive radiation of >500 species of cichlid fish has occurred in record time, making Lake Victoria one of the most widely cited model systems in evolutionary biology. To reconstruct the dynamic state of the Lake Victoria ecosystem and its biodiversity from the late Pleistocene to the present, we analysed multiple biotic and geochemical proxies (pollen, biogeochemistry, invertebrates, and fish fossils) from a transect of four sediment cores that trace the development of the highly productive littoral zone and the less productive pelagic/profundal zones through time. We present a comprehensive analysis of past vegetation and ecological changes throughout the modern lake's history to assess how the long-term dynamics of the ecosystem interact with the evolution of its biota. Pollen data reveals the manifestation of climatic fluctuations, which suggests major transitions between rainforest and savannah grasslands. Additionally, other proxy datasets also indicate a dynamic history of lake filling that likely occurred over a longer timescale than previously reported. The integration of past ecological and limnological changes recorded in the chronostratigraphic sequences of Lake Victoria provides valuable insights into the interactions between climatic shifts, the development of an ecosystem, and the evolution of species diversity.

Diatom-bound nitrogen isotopes as a paleo-proxy in lacustrine environments: a preliminary report

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Diatom frustules are well preserved in marine and lacustrine sediments over hundreds or even thousands of years. They contain minute amounts of intra-crystalline organic matter that is thought to be protected by the silica against diagenetic alteration. Previous applications have shown that the $^{15}N/^{14}N$ ratio of the organic nitrogen contained in these frustules (the diatom-bound $\delta^{15}N$, or $\delta^{15}N_{DB}$) can be used as a proxy for nutrient cycling in the polar oceans, and that it is not affected by diagenetic effects. However, the applicability of this paleo-proxy to lacustrine sediments has never been tested.

One goal of this study is to validate whether the organic nitrogen contained in diatom frustules is indeed protected against diagenetic alteration. For this purpose, we will analyse and compare the $\delta^{15}N_{DB}$ and N_{DB} content of sediment trap, surface sediment and downcore sediment material from a time-series study of varved sediment cores from Nylandssjön, a lake in northern Sweden. We will also measure the $\delta^{15}N_{DB}$ and N_{DB} content from degradation experiments of diatom cultures, in order to assess diagenetic aspects on timescales from days to decades.

Another goal of this study is to explore the use of $\delta^{15}N_{DB}$ to reconstruct the history of nitrogen dynamics in Swiss lakes. Provided that the $\delta^{15}N_{DB}$ record is unaffected by diagenesis, it should record past changes in the N input/output processes and/or internal N cycling processes within a given lake. We chose to investigate the sedimentary record of the well-studied Lake Baldegg in Switzerland, a eutrophic lake with varved sediments between 1885 and 1995, which is being artificially ventilated since 1982. We will present the $\delta^{15}N_{DB}$ down-core record of Lake Baldegg sediments and compare it to other sedimentary proxies (e.g., bulk isotopic composition, elemental composition and chlorophyll *a*), as well as hydrochemical datasets from the lakes' monitoring program (e.g., nutrient concentrations), allowing us to constrain the environmental context of sedimentation, and to disentangle the multiple controls on the $\delta^{15}N_{DB}$ in Lake Baldegg in the recent past.

Novel techniques for reconstructing relative changes in past UV-B flux

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Many climate and environmental parameters can now be reconstructed over geological timeframes via biological, geochemical, biogeochemical and sedimentological proxies. However, reconstructions of past variations in UV-B radiation are comparatively limited, due to a lack of suitable proxies. Given the threat that UV-B radiation poses to both human and ecosystem health, there is a need to better understand past UV-B flux to appreciate the challenges that elevated surface UV-B levels could pose in the long-term.

Sporomorphs (pollen and spores) contain UV-B absorbing compounds (UACs) in the sporopollenin biomacromolecule which forms their outer walls. UACs function as a natural ‘sunscreen’, protecting the gametes within the sporomorph from damage caused by exposure to UV-B radiation. Empirical and experimental studies have determined that UACs are ubiquitous in sporopollenin, and that the quantity increases with increased exposure of the parent plant to UV-B. Because sporopollenin is highly resistant to decay, sporomorphs are abundant in the fossil record, and their UAC content stays stable over time. Sporomorphs therefore offer an avenue for the reconstruction of surface UV-B flux through time.

We present preliminary results from our project in which we are using Fourier Transform infrared (FTIR) microspectroscopy to measure UACs within sporomorphs from Lake Ohau (44°16.782’S, 169°55.480’E, New Zealand) sediment records. One of our project aims is to produce the first sporomorph-based UAC record from the Southern Hemisphere. To deliver this, we will target at least two taxa native to New Zealand within the Ohau record, to produce a high-resolution (biennial) record for the Maunder Minimum, and a low-resolution record for the entire Holocene. The data will be used to study key atmospheric research issues, including if Maxima and Minima respond the same way to forcing, if Schwabe cycles can be detected in high resolution sporomorph UAC records, and if variations in surface UV-B derived from the Ohau record can be linked to longer-term processes related to orbital forcing. Data from this study will be compared to a complimentary dataset using a similar sampling strategy from Nar Gölü, (Türkiye) in order to undertake the first interhemispheric comparison of UAC records of UV-B variation through time.

Constraining Black Sea nitrogen cycling during the Holocene using lipid biomarkers

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The study of marine basins under anoxic conditions can provide perspective on the current deoxygenation of the modern global ocean under anthropogenic warming and associated feedbacks with the marine nitrogen cycle. At present, a thorough understanding of the nitrogen cycle on timescales exceeding the observational record, particularly in anoxic environments, remains elusive. Today the Black Sea is the world's largest permanently stratified anoxic basin; it is a hyposaline (18-22 psu), vertically-stratified sea, with limited connection to the global ocean through the Bosporus Strait. However, the basin has only been anoxic below 200 m water depth (Arthur & Dean, 1998) since ~7.5 ka when post-glacial sea-level rise caused spillage of seawater over the Bosporus sill. Before this time it was a more oxygenated, fresh-water lake. Records from the Black Sea over the Holocene can therefore provide insight into the nitrogen cycle dynamics under drastic environmental changes.

Using a sediment record from the Black Sea spanning the Holocene (0 – 15 ka), this study aims to better constrain the marine nitrogen cycle in an anoxic environment using organic geochemical approaches. These approaches include the use of high-resolution accurate mass spectrometry (MS) to identify and semi-quantify a range of lipid biomarkers. The target biomarker in this study include (1) heterocyste glycolipids (HGs), associated with N_2 fixing cyanobacteria (Bauersachs et al., 2010; Bale et al., 2019); (2) isoprenoidal glycerol dialkyl glycerol tetraethers (GDGTs), including those associated exclusively with ammonia oxidising archaea (Sinninghe Damsté et al., 2002); and (3) bacteriohopanetetrols (BHPs), including bacteriohopanetetrol (BHT-x), which is y associated with marine anaerobic ammonium oxidizing (anammox) bacteria (Schwartz-Narbonne et al., 2020). Combining these records with total organic carbon, total organic nitrogen and redox-sensitive trace element data, we aim to better understand the marine nitrogen cycle under changing anoxic conditions, and its potential links to broader global climate dynamics.

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Posidonia oceanica interaction with sea floor sediment of Kornati islands, Croatia

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Coastal vegetated ecosystems are important carbon storage for half of the carbon in marine sediments and soils. Seagrass meadows have exceptionally high carbon storage capacity which contributed to their recognition as significant Blue Carbon sinks. Their protection and restoration are included in climate change adaptation strategies. One of the seagrass species that notably modifies its growing substrate is the endemic *Posidonia oceanica* (L.) Delile from the Mediterranean Sea that occupies coastal areas of up to 40 metres of water depth. In addition to its carbon sequestration power, *Posidonia oceanica* contributes significantly to seawater oxygenation and sediment stabilisation. Studies of the interaction of *Posidonia oceanica* with sediments along the eastern Adriatic coast are scarce. The aim of this study was to provide a conclusive palynological, mineralogical, geochemical, and microbial overview of the *P. oceanica* substratum in the Vrulje bay of the Kornati islands. A detailed palynological analysis was conducted on a 269 cm long core in order to obtain paleovegetational background. Furthermore, the core was analysed for mineralogical composition and grain-size. The geochemical investigation included XRF core scanning, organic and inorganic carbon, and total nitrogen measurement, whereas ^{14}C dating results offered a chronological framework. The high-resolution seismic survey of the Kornati channel was also performed in order to gain insight into the subsurface of the coring area. Archaea and bacterial communities were investigated by environmental DNA metabarcoding. Our study provided the Holocene paleorecord of the formation and growth of the *P. oceanica* matte in the investigated area. We made new estimates on the seagrass carbon storage and organic carbon accumulation rates in the sediments during the last 8140 years B.P. The analysed sediment core further offered exhaustive evidence of the paleoenvironmental changes that occurred due to the Holocene climate and sea level variability. The obtained data are important for understanding the storage of carbon in sediments accumulated directly below the *P. oceanica* meadow.

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The CLIMCOST Project: Recurrence of extreme weather events in Western Europe from a Holocene perspective and its implication for the management of coastal ecosystems in Galicia

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Climate predictions of precipitation and atmospheric circulation at decadal timescales are not entirely reliable due to the lack of quantitative reconstructions for long time periods. CLIMCOST project aims to evaluate climate variability during the late Holocene and identify recurrent patterns of extreme climate events and their impact on the coastal systems of Galicia (Northwest Iberia, Spain). To this end, quantitative reconstructions of decadal-scale precipitation in Western Europe are being carried out beyond the current instrumental record, to identify the interactions between the modes of climate variability in the North Atlantic, their relationship with the latitudinal position of the jet stream and the storm tracks. This will allow: 1) a much more complete understanding of the regional atmospheric circulation; 2) its direct relationship with extreme hydroclimatic events; and 3) the impact on coastal systems. To this end, we are using sedimentary archives and applying new approaches in geochronology, proxy calibration, advanced statistical modelling, and biogeochemical techniques.
CLIMCOST looks for forming a triple helix, integrating research, management, and society to provide key information on the relationship between jet stream migrations and their impact on coastal systems. The Holocene perspective of the project is crucial to analyse the resilience of ecosystems, generate an early warning system for risks and threats, improve predictive capacity in the short, medium, and long term and ensure the sustainability of aquatic ecosystems. All of this in a region where economic activities along the coast have always been the driving force of its economy and as is being demonstrated, is highly sensitive to rainfall variability in the context of current climate change.

A Late Holocene δ18O paleoclimate record from the afro-alpine Lake Garba Guracha, Bale Mountains Ethiopia: implications for human occupation/abandonment

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The Late Holocene, being a period when human footprint in paleoenvironmental archives became increasingly apparent, records important information about how early humans adapted to ever changing climatic conditions. Lake Garba Guracha is an afro-alpine cirque lake located in the Bale Mountains National Park in the Southeastern highlands of Ethiopia. The reconstructed age depth model of 10 years/cm makes it one of the best climate archives in the highlands of Eastern Africa. A total of 15.5 meter core recording 16 ka of sedimentation was retrieved from the lake. Previous works done on the archive include: (i) establishing the age-depth model and determination of sedimentation rates using bulk sedimentary organic matter, bulk *n*-alkane and charcoal ^{14}C ages; (ii) multi-proxy paleoenvironment reconstruction using charcoal, diatoms, biomarkers, and stable isotopes. Results from these works show a strong variability recorded in late Holocene that represents the termination of the African Humid Period (AHP) and increased fire intensity. This study focuses on the topmost sedimentary succession of the core representing the late Holocene (~5 ka to present) and implements $\delta^{18}O_{sugar}$ extracted from organic matter derived natural sugars in high resolution (every 4 cm). Variability in $\delta^{18}O_{sugar}$ record can be used as a proxy for lake evaporation history· Combing with other important proxies such as n-alkane and charcoals and archaeological studies will shade light on a possible synergy of climate and humans in this high alpine ecosystem.

Climate and land-use effects in southwestern Morocco during the last three millennia

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The southwest of Morocco is considered to be an area of refuge within the Mediterranean region, hosting the endemic tropical Argan tree. This region is presently subject to severe droughts, desertification, and land degradation, and likely facing increased climate variability and socio-economic stress in the future. Here, we use the stable hydrogen and carbon isotope composition (δD and δ13C) of plant-waxes in a high-resolution marine sediment core (GeoB8601-3) collected off Cape Ghir in southwestern Morocco, in combination with published data on pollen and XRF element ratios from the same archive. We aim to reconstruct the hydroclimate and vegetation history during the last 3000 years. Stable carbon isotope compositions of leaf waxes (δ13Cwax) show that natural vegetation in southwestern Morocco consists of C3 plants. Minor variations in δ13Cwax were positively correlated to changes in stable hydrogen isotope compositions of leaf waxes (δDwax) before 700 CE. Changes in rainfall amounts and water use efficiency indicate a clear vegetation response to precipitation changes and thus to climate forcing. After 700 CE, δDwax and δ13Cwax became de-coupled suggesting that the plant wax discharge and their isotope signals were no longer solely controlled by climate; the waxes likely mainly originate from the lowlands and carry an enriched (dry) δD signal but a depleted 13C signature. The depletion of δ13Cwax correlates with the increased Argan pollen concentration in the record. The period between ~700 and 900 CE coincides with the Arabization of Morocco which had an impact on the demographic composition of the country leading to new agricultural habits and, as a result, on the land-use triggering a higher erosion of lowland material by the Souss River.

Sixty years scientific deep drilling in land, ice and sea floor: the north Andean guide to the Quaternary

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We sketch the initial history of collecting deep cores in terrestrial basins, marine sediments on the ocean floor, and arctic ice cores to study the environmental and climate change. Subsequently, we focus on the development of long records from the Northern Andes. In the Bogotá basin, the 540 m long pollen record Funza09 from ancient Lake Bogotá reflects the last 2.25 Ma with 1200yr resolution. The grain size record continues up to the bedrock at 586 m depth possibly reflecting the complete Quaternary. Developing a robust age model has been challenging. We used orbital tuning and curve matching between the marine ∂18O record and the peaks in abundance of *Alnus* for the last 1 Ma, when extensive *Alnus* swamp forest surrounded the lake during interglacial conditions. Ancient Lake Bogotá was born 1.4 Ma and lost its water body at 27 ka. Before 1.4 Ma a drainage system with swamps and lakes covered the surface of the slowly subsiding basin floor while forest occurred on higher grounds. In the Fúquene basin, the 58 m long composite record from Lake Fúquene covers the 284-27 ka interval with 60 yr resolution. The last 27 ka were covered by record Fúquene-2 though at lower resolution. Absence of a seismic reflectance profile across the basin prevented identification of the optimal drilling location. In the basin of Lake La Cocha the last 14 ka were analysed at ~25 yr resolution bringing geological and human dimensions of climate change together. We show the relevance of high-resolution pollen analysis.

Feeding a Digital Elevation Model of the Northern Andes with Funza09 upper forest line positions of the last 1 Ma allowed the spatial reconstruction of the hyper-diverse high-elevation alpine ecosystems, the páramos. The operating Flickering Connectivity System drove speciation to high levels. In contrast, the montane forest experienced a continuous connectivity driving latitudinal migration of pre-adapted forest taxa. We show the relevance of high-resolution pollen analysis in deep continental records, and address the various challenges and limitations of working with deep cores based on our 50 years of experience in continental core drilling.

Character and behaviour of Qaanaaq (Piulip Nunaa) glaciers in north-west Greenland (Kalaallit Nunaat) since the Little Ice Age

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The centennial and decadal timescale response of land-terminating glaciers is important for projecting future changes to Arctic sub-polar glaciers and hence meltwater and sediment fluxes. This study analyses prominent moraines, the proglacial areas and contemporary glacier character on the Qaanaaq peninsula (Piulip Nunaa) in NW Greenland to determine geometric changes of glaciers since the neoglacial maximum (Little Ice Age) and to interpret glacier behaviour then and now. Specifically, we made ice surface reconstructions and ice thickness datasets to determine geometric changes and likely thermal regime during the LIA, and a suite of field observations and measurements at five of the outlet glaciers of high-resolution topography, geomorphology and sedimentology, and glaciology. LIA moraines and proglacial outwash surfaces are predominantly composed of subglacially-mobilised boulders and thus related to areas of former temperate basal ice. In contrast, ice-cored lateral moraine ridges of sub-angular boulders are related to ice-marginal areas of (former) cold-based ice. Other ridges or mounds of englacial and supraglacial debris, and geometric and sinuous ridge networks are also associated with ice-marginal cold-based ice. Contemporary ice-margins and ice surfaces exhibit many features to suggest cold-based ice, including convex surface gradients, no crevasses, few but large supraglacial streams usually associated with medial moraine and sediment drapes and ridges emanating from thrust planes, for example. Overall, it is apparent that since the LIA these glaciers have retreated, thinned and evolved from more temperate to more cold-based conditions and behaviour.

Modelled palaeoclimate and ice dynamics in the low latitude Peruvian highlands

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The dynamics and response of tropical glaciers to past global climate changes are poorly understood. This is despite tropical glaciers being highly sensitive to climate and important indicators of recent climate change. We use the Parallel Ice Sheet Model (PISM), a hybrid, three-dimensional, numerical, finite-difference, shallow ice sheet model to model palaeo-glaciation within the northern Peruvian highlands.

Lagunas de las Huaringas is a low-latitude location that was previously glaciated at a relatively low elevations (3,900-2,600 m a.s.l.), presumably during the Last Glacial Maximum (LGM), but which is now completely deglaciated. Previous work has reconstructed a series of valley glaciers, from which an LGM temperature reduction of 6.5-8.8℃ has been inferred from the geomorphology.

Here we used PISM to reconstruct glaciation in this location, using the model to develop our knowledge of the climate conditions required for glaciation of this low-latitude low-elevation site. We implemented a range of palaeoclimate scenarios, using stepped temperature cooling and precipitation fractions, and allowed the model to run to steady state conditions. All model outputs were compared to reconstructed glacial extents from mapped glacial geomorphology, in order to determine the ‘best-fit’ climate conditions for the glacial geomorphic evidence. Model runs provided three-dimensional glacier geometries from which ice mass parameters such as palaeo-equilibrium line altitudes, surface mass balances, area, volume, ice thicknesses, velocities could be determined. Our model results provide insights into the sensitivity of these former tropical glaciers to different climates and model parameters, providing an understanding of the former climate envelope which these ice masses could form.

First analysis of neoglacial geomorphology in the Nevados de Chillán volcanic complex (36,8°s – 71,4°w), Central-South Chile

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The Nevados de Chillan volcanic complex (NCVC) is a set of stratovolcanoes aligned with NW-SE orientation and with an area of about 86 km^2. Located in the Southern Volcanic Zone of the Andes, the complex consists of two main volcanic edifices that reach a little above 3100 m above sea level (asl), surpassing the regional average summits elevation by almost 1000 m asl. The complex also lies near what is considered the northern rim of the largest extension of the Pleistocene Patagonian Icesheet during the global last glacial maximum (LGM), which likely resulted from a persistent northern shift of the Southern Hemisphere westerlies. The NCVC began its activity during the Middle Pleistocene (~640 ka) and is still active today, with many glacial-interglacial periods coeval with eruptive cycles. There are almost no glaciological studies, except for a recent mass-balance monitoring of the largest glacier of the complex, but there is an absence of research reconstructing the glacial history of the NCVC. The relief formed during the LGM is characterized by large U-shaped valleys and glacial cirques that were covered by vegetation throughout the Holocene. However, there are also "fresh" glacial landforms above 2000 m asl. resulting from more recent glacier advances. The oldest historical records date from 1862 (end of the Little Ice Age), suggesting the existence of larger glaciers on these volcanoes. We characterize these landforms to develop a glacier chronology and study the climatic factors leading to glacier fluctuations. Particularly, we focus on the analysis of neoglaciations, using field mapping, satellite, and aerial imagery, and morphometric analysis of glacial deposits and landforms such as moraines, streamlined landforms, and glacially polished surfaces that are present around the whole complex. These landforms have different degrees of preservation, different distribution, and variable heights, which enable detailed reconstruction of glaciers in the recent past. The best-preserved moraines are in the western flank of the complex and their lower elevations vary between 1933 and 2350 m asl, indicating an equilibrium-line altitude (ELA) of ~2619 m asl, equating to an ELA depression of ~220 m relative to present.

Depositional record of the Lower Aare Valley region, northern Switzerland

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The foreland of Northern Switzerland has been exposed to repeated advances of Alpine glaciers during the Mid- and Late-Pleistocene. While those glacial advances had a lasting impression onto the landscape evolution, constrains of timing, quantity and extent remain sparse. To further the understanding of Quaternary environmental change, a promising archive was found in the infill of the overdeepened Gebenstorf-Stilli Trough and the glaciofluvial palaeochannel system of the Lower Aare Valley. In an extensive scientific campaign, ca. 350 m of drill cores as well as outcrop samples were recovered. Sedimentological and petrographic results in combination with a new luminescence chronology reveal multiple phases of glacial and glaciofluvial activity. This provides insights into regional ice-margin positions and refines our understanding of glacial sediment yields.

Unravelling the maximum extent of Middle Pleistocene Glaciation in the Ybbstal Alps, Austria

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Unlike deposits from the LGM in Austria (Würm Pleniglacial; MIS 2) the glacial records from the Middle Pleistocene glaciations like Riss Glaciation (MIS 6) and older are usually fragmentary, concealed and significantly overprinted by postz-depositional processes (e.g. erosion, weathering and …) of the Late Pleistocene landscape evolution. This specifically applies to terminal positions of the ice tongues.
Contrary to parts in Western Austria, where extent, terminal positions and size compared to the LGM extent from the Mindel- and Riss glaciations are well constrained, our study area shows gaps in this regard.
The Ybbstal Alps, with peaks of 1800 m and valleys of around 500 m in elevation, a unique sedimentological archive is preserved that allows the reconstruction of glacier dynamics at the terminal positions of the Enns and Ybbs glaciers. Our reconstructions are based on sedimentological data and mapping results of several gravel pits and additional sediments from valley flanks. Deposits generally show at least four major facies assemblages, starting with fluvial to distal glaciofluvial deposits (1) from the phase before the Riss climax. Followed by glacial diamictons (2) which are overlain by rhythmites (3) that are associated with a glaciolacustrine environment. Finally, the successions generally end with several metres of deltaic conglomerates (4) indicating a rapid and quick aggradation due to high sediment influx associated with glacial retreat. The record from the pre-Riss includes glaciogenic and deltaic sediments that point to a much larger glaciation. Our preliminary results indicate a much larger glaciation during the Middle Pleistocene in the Eastern Alps than previously thought.

The last glacial termination in the Atlantic Iberian mountains: insights from lake sediments in Serra da Estrela (Portugal)

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Understanding the climate evolution of the last glacial termination for sensitive and transitional climatic zones such as the Atlantic Iberian mountains is crucial to estimate potential changes in regions affected by current glacial melting. We present an 8.5-m-long record including detailed sediment analysis from Lake Peixão, a pro-glacial lake in the Serra da Estrela Mountain (Central Portugal). The age-depth model relies on a Bayesian approach that includes 16 AMS ^{14}C dates and ^{210}Pb-^{137}CS measurements, and robustly dates the lake formation at 14.7±0.32 cal. ka BP. The sediment sequence is composed of 5 lithological units: U1) sandy and unsorted fluvioglacial lacustrine deposits; U2) massive fluvioglacial silty lacustrine deposits (863-790 cm below surface (bsf); 14.7-13.8 cal. ka BP); U3) water current fluvioglacial lacustrine silty deposits (790-766 cm bsf; 13.8-12.9 cal. ka BP); U4) laminated/banded silt/clay lacustrine deposits characterised by sediments from ice-covered lake periods and episodic events of ice and snow melting (766-752 cm bsf; 12.9-11.7 cal. ka BP); and U5) massive muddy lacustrine deposits (752-0 cm bsf; 11.7cal. ka BP-present). The occurrence of U2 to U4 deposits matches the transition from glacial cold (U1) to net warm postglacial conditions (U5). These changes in the sedimentary facies reflect the different phases of the deglaciation, including episodes of very low sedimentation rates related to the Intra-Allerød Cold Period and the coldest phase of the Younger Dryas. The robust chronology of Lake Peixão shows the potential of Iberian pro-glacial lakes for dating deglaciation processes in the westernmost glaciated region of the Iberia Peninsula and will lead to unprecedented decadal-to-centennial timescale Holocene climate reconstructions in this key region between the Atlantic and Mediterranean climate impacts.

The role of topography in ice-marginal landform development at Fingerbreen, Østre Svartisen, Norway

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Mountain glaciers are sensitive indicators of climate change and many records demonstrate that their rate of recession has accelerated significantly in recent decades. Loss of ice in mountain regions has critical implications for water resource management, catchment-scale sediment budgets and ecosystem response. The wealth of geomorphological and sedimentological data left behind during glacier retreat can be used to help understand the complex response of glaciers to changes in climatic and topographic conditions. Improving understanding of these controls is imperative for both refining modelled predictions of glacier recession rates and for modelling climatic change from the glacial geological record.

We present the results of investigations at Østre Svartisen, Norway (66 °N), focussing on the temperate plateau icefield outlet glacier Fingerbreen. The research examines the geomorphological and sedimentological evidence deposited during overall retreat from the Little Ice Age maximum (~ 1750 AD) to present day. Section logging of moraines and flutes provides a detailed insight into changes in sediment delivery to the ice margin as glacier recession progressed. We show that the topography of the foreland strongly influences the shape of the ice margin and guides meltwater flow, causing variability in moraine-forming processes and preservation potential. This research demonstrates the complex relationship between the sedimentary record and glaciological, topographic, climatic conditions.

Last Glacial Maximum and early deglaciation in the Stura Valley, southwestern European Alps

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We combined data from geomorphologic surveys, glacial modelling, and ^{10}Be exposure ages of boulders on moraines, to investigate the Last Glacial Maximum (LGM) and the early retreat glacial phases in the Stura Valley of the Maritime Alps. We used the exposure ages to reconstruct the timing of the LGM and that of a standstill or readvance that interrupted the post-LGM withdrawal. We mapped and dated a LGM frontal moraine to ~22 ka and a post-LGM moraine, some ~ 7 km from the maximum external limit of the LGM, to ~19 ka (Bühl stadial). This morpho-chronologic succession is congruent with that obtained in the adjacent Gesso Valley and, combined with the similarity of Equilibrium Line Altitude values, demonstrates a consistent glacial response in the Maritime Alps to climatic forcing.

Our data are chronologically consistent with those of the southern flank of the European Alps, stressing not only a general synchroneity of the LGM across the various sectors, but also that of a LGM recessional standstill or readvance at ~22 ka. The short distance between the LGM moraines and the recessionary phase moraines indicates a modest variation in the mass balance of the Maritime Alps glaciers during this time interval. A similar modest variation between LGM and the first recessional phase glacier mass balance is also found throughout the western sector of the Southern Alps but is considerably more pronounced for the glaciers of the central-eastern sectors. The heterogeneous response to these same climatic events across the Alps can be explained by the interplay between the moisture supplied by southern currents sourced in the Western Mediterranean and that advected by the westerlies sourced in the North Atlantic, which likely affected the various sectors of the Southern Alps differently.

Understanding rapid deglaciation at Mittelbergferner through a sediment-landform association lens

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Glaciers in the Ötztal Alps (Austria) have been undergoing retreat since the "Little Ice Age" in 1850, leaving a complex geomorphic record of subglacial features, glacial and fluvial deposits, and slope-derived talus. By systematically describing and studying these features in modern alpine glacial environments, we can obtain clues as to what is driving these changes and how they are responding to the current climate conditions the Earth is facing. Mittelbergferner is one of the largest glaciers in the Ötztal Alps, and also a tourist destination in the Pitztal area, where there is an extensive suite of hitherto unstudied supra- and subglacial morphotypes that require documentation and interpretation. Here, a high resolution geological-geomorphological map is presented for the East and West lobes of Mittelbergferner based on photogrammetric data, which will be the main tool for studying sediment-landform assemblages in the area. Some of the observed features include the glacio-structural framework, drainage networks, flutes, small moraines and talus slopes. There are also signs of imminent detachments from the main glacier at the West lobe, as well as exposed bedrock within the ice and associated trails of diamicton, which are indicators of decrease in accumulation and consequent retreat. Other questions arise regarding supraglacial debris, sediment distribution and the precise role that dead ice plays on sedimentary architecture during the retreat process. The analysis of the landforms associated with ice recession at Mittelbergferner will contribute to understanding the sediment dynamics operating at rapidly retreating glaciers, offer additional perspectives on processes that are occurring in comparable glaciated areas of the Austrian Alps, and possibly give insight into ice margin stability.

Glacial Geomorphology of the Brooks Range, Alaska, U.S.A.

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Global and regional estimates of glacier mass and area change are poorly constrained prior to 2000 due to a lack of data, particularly in high latitude areas. This impedes our ability to comprehend and contextualise observed glacier mass loss, particularly when investigating changing rates of mass loss. This can be resolved by extending the glacial record back in time, to improve understanding of how glaciers have changed in this region under a longer-term time series of climatic change. The geomorphological reconstruction presented here will form part of a larger project, incorporating geomorphology, photogrammetry and modelling techniques to accurately constrain and project Brooks Range glacial change.

This study aims to investigate the glacial geomorphology of the Brooks Range, Alaska, and to reconstruct glacier behaviour since the “Little Ice Age” (LIA), by reconstructing the LIA glacial maximum and comparing it to various temporal points between then and 2022 AD. We use mapped glacial features to infer LIA glacier outlines and calculate their approximate area. In some areas, glacier outlines digitised from topographic maps are available and were used as timestamps to correlate glacial features with their approximate age, as well as to evaluate changing rates of glacier wastage between LIA inferred outlines and 2022 AD outlines. We derive 2022 AD glacier outlines from Sentinel-2 imagery, using a band ratio method to automatically identify glaciers followed by vectorisation and manual editing to produce a Brooks Range glacier database. Generation of these outlines enables quantification of glacier area change from the LIA to 2022 AD, as well as higher accuracy in the modelling phase of the larger project.

Our new geomorphic maps will allow us to derive glacier area change across the Brooks Range, and constrain rates of change to analyse how Brooks Range glaciers are responding to changing climatic forcings in the region. This will enable insights into the style and manner of the neoglaciation and deglaciation in the Brooks Range. Further, the results of this investigation will be used to inform the methods used as part of the larger project.

Geometry and reconstruction of former glacial formations in the El Cervunal obturated depression (Sierra de Gredos, Iberian Central System)

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The glacial chronology in the Central System of the Iberian Peninsula (ICS) has been obtained mainly by applying Cosmogenic Radionuclides Exposure (CRE) techniques. The desirability of validating these data from sedimentary sequences housed in lacustrine depressions associated with ancient glaciers, made necessary specific investigations combined geological, geomorphological, and geophysical techniques. Here we present the most recent results obtained with one of these works carried out in the sedimentary infill of El Cervunal depression (CD). The CD is a flat plateau located at 1800 m asl (average altitude) in the interfluve between the valleys of Gredos and Pinar, two former glaciers (paleoglaciers) whose lateral moraines were the ones that carried out a process of obturation of this depression, forming a semi-endorheic basin during the last glacial cycle. The study of the sedimentary infill of CD means of a combined interpretation of near-surface geophysical techniques supported by geomorphological and borehole data. A set of 1D and 2D near-surface geophysical methods, including electrical (Vertical Electrical Sounding and 2D Electrical Resistivity Tomography), seismic (2D Seismic Tomography and 1D Refraction Microtremor) and Magnetic Resonance Sounding techniques, were used to test their applicability in providing better insight on the infill nature and geometry. As a result of the study, we obtained three geophysical units and five sub-units with their geological interpretation. Unit 1, includes alluvial-plain and alluvial-fan deposits, classified as a postglacial sequence (post ~10 ka). Units 2 and 3 below the postglacial unit were interpreted as glacial sequences including kame (glaciogenic and fluvio-glacial) and morainic deposits, respectively (from ~10-12 ka to ~25-27 ka). As a global result, we can say that the CD had a complex evolution where erosive-sedimentary processes predominate, but structural factors must also be considered. Finally, five well-differentiated stages can be established: pre-glacial, maximum glacial extension, trough obturation, glacial retreat and periglacial-postglacial.

Evolutionary sequence of Pleistocene glaciation in the Sierra de Guadarrama National Park

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The Sierra de Guadarrama (SG) occupies the eastern sector of the Iberian Central System, the central part of which corresponds to the Sierra de Guadarrama National Park (SPNG). It is a medium-range Mediterranean mountain, segmented by fault blocks, with a predominance of crystalline rocks (variscan and pre-variscan basement) and, in local areas, sedimentary cover (Cretaceous and Tertiary lithologies) and Quaternary superficial deposits. The summits in the SGNP rise to more than 2000 m asl (Pico de Peñalara, 2428 m asl) with frequent morphologies originated by ancient glaciers. In this area, 79 palaeoglaciers developed between 2413 m asl (maximum altitude glacial cirque) and 1490 m asl (minimum altitude melt front) have been identified. Most of these glaciers were cirque and slope glaciers and only exceptionally valley or plateau glaciers. All glaciers belong to the last glacial cycle (LGC) and their evolutionary sequence and chronology has been established in three main stages that agree with the regional model developed in other areas of the Central System: the Maximum Ice Extension (local MIE), assigned to both MIS2 (around 26 ka BP) and MIS3 (around 35 ka BP); a later stage of retreat-advancement-stabilization, ending around 17/15 ka BP; and deglaciation ending around 11-10 ka BP. The estimations allow the establish the ELA during the Glacial Maximum at 1926 m asl, indicating a 1000-1200 m of depression compared with the estimated present-day ELA.

Fingerprinting abrupt climate change in the West of Ireland: A high-resolution timeline of deglaciation and landscape evolution

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Thoroughly codifying and examining paleoclimatological data ("fingerprinting") from diagnostic sites provides unique insights into the environmental past that are rarely achievable by model simulations. Fingerprinting a site tells a robust, high-resolution story of climate change for a specific location, allowing for a continuous timeline to be reconstructed through various methodologies that will ultimately refine models of larger scale. The concept of fingerprinting has been tested at a site on the west coast of Ireland, situated adjacent to the North Atlantic Ocean. This unique setting allows multiple techniques to be applied to reconstruct the nature of climate variability on Europe's maritime margin since the end of the Last Glacial Maximum (LGM). Techniques employed focus on the use of glacial geology coupled with lacustrine sedimentology and geochronology. Numerous glacial features have been identified at the site that provide evidence for the timeline of deglaciation and evolution of the landscape; this is supported with dating techniques and lake sediment core analysis. Cosmogenic Beryllium-10 dating has been employed to return direct ages from glacial evidence by using erratic boulders with beryllium-containing quartz. Using a previous study (N=11) and adding additional samples (N=9) at multiple elevations on and next to Ben Bury mountain in the Mweelrea massif, we have produced a directly dated timeline of ice sheet deglaciation since the LGM and subsequent cirque glaciation. Concurrently, a sediment core extracted from an adjacent lake contains a continuous record from its formation to the beginning of the Holocene. Dating methods including Carbon-14 and varve counting allow this core to match and fill-in the record of deglaciation obtained from cosmogenic dating of glacial deposits. Our preliminary results suggest that current paradigms of recent abrupt climate change may need refining. Fingerprinting Ben Bury has provided a yardstick for local deglaciation through direct dating across different elevations and the following snowline reconstruction. Zero-degree isotherms indicate that the local snowline was high as early as 18ka, suggesting deglaciation was occurring rapidly no later than the end of the LGM, and there is no distinct Younger Dryas advance afterward.

Subdivision of the Little Ice Age in the Alps

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The “Little Ice Age” (LIA) can be considered, on the one hand, as a period of repeated and far-reaching glacier advances during the last millennium, on the other hand this term is also used to address the period of relatively low temperatures following the Medieval Climate Anomaly (MCA) and preceding the modern warming. The end of the LIA in the Alps is in general set to the mid-19th century, i.e., to the approximate date of the last glacier maximum. However, the onset of the LIA is not so well defined and is now usually placed in the 14th century and thus around the first general glacier maximum after the MCA. New results, based on tree-ring dating of several hundred years old and in-situ buried trees at Mont Miné and Morteratsch glaciers, show that this glacier advance preceding a 14th century maximum began no later than in the second half of the 13th century.

This early-LIA advance of Mont Miné and Morteratsch glaciers is consistent with results obtained at other Alpine glaciers and coincides with relatively cool summer temperatures in the late 13th and 14th century. The first LIA-advance phase in the Alps culminated in the late 14th century, followed by a retreat period with reduced glacier extents and minor advances, which was finally followed by the historically well-known LIA-advance period from the end of the 16th century onwards. The Alpine glacier record in combination with summer temperature reconstructions suggest a subdivision of the LIA (approx. 1260 to 1860 CE) in the European Alps into an early phase (1260-1380), an intermediate period (1380-1575) and a main phase (1575-1860).

Chronology and Equilibrium Line Altitudes of paleoglaciers along the southern fringe of the European Alps during the Last Glacial Maximum

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During the Last Glacial Maximum (LGM), most of the European Alps was covered by an extensive and complex palaeoglacier network. Only along the external fringes of the Alps did isolated, smaller valley glaciers and ice caps in the order of 1 to 100 km^2 develop. These smaller glaciers constitute excellent palaeoclimate proxies as they likely responded very dynamically to changes in temperature and precipitation. However, they have been studied only in a few areas so far, without the application of a consistent methodological approach.

Here we present a new synthesis of isolated mountain glaciers along the southern fringe of the Alps during the LGM, ranging from the Carnic and Julian Prealps in the East to the Maritime Alps in the South-West. Geomorphological surveys were carried out both using remotely sensed data and through targeted fieldwork. Based on these data, palaeoglacier 3D geometries and Equilibrium Line Altitudes (ELAs) were reconstructed numerically in a GIS environment. Age control is selectively provided through ^{10}Be and ^{36}Cl surface exposure dating on moraine boulders. This allowed not only to assign moraine ridges to an LGM age, but also to evaluate if ice advances occurred simultaneously across different parts of the mountain chain and if they were in or out of phase to larger Alpine glaciers.

We demonstrate that ELAs across the southern Alpine fringe were highly variable during the LGM, reflecting the diverse climatic conditions that characterised the individual mountain ranges. This provides important insights into the larger scale atmospheric circulation and may be used to validate glacier and palaeoclimate modelling studies.

Real-time coarse cryogenic cave carbonate formation in a Pyrenean ice cave

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Coarse cryogenic cave carbonates (CCC_{coarse}) are rare crystals and aggregates thereof that form in caves when water freezes in a semi-closed system in ice pools. Freezing provokes the loss of CO_2 and the segregation of solutes, leading to the precipitation of CCCs. That pool model is accepted for the formation of CCC_{coarse}; however real-time formation of CCC_{coarse} has never been observed. Since 2018 we have observed the formation of CCC_{coarse} in two pools in a small gallery in the Sarrios 6 ice cave (Central Pyrenees). The floor and ceiling of this gallery are covered by ice. The mean annual air and rock temperatures have remained below 0°C since 2014, thus indicating the presence of permafrost in this gallery. However, many dripping points feed a pool located at the entrance of the gallery. After intense rainfalls or days of snow melting, the drips feed that pool and eventually lead to flooding of the gallery. We have observed the formation of two pools since the gallery opened due to the ice retreat in 2016. The CCCs form ball-shaped aggregates 9-10 cm in diameter. These balls, locally called comuños, consist of thousands of carbonate crystals, including elongated, rhombohedral, and globular crystals (≥2 mm) showing in radial structure. These crystals are supported by an ice matrix. Analyses using single crystal cryogenic X-ray diffractometry performed on frozen samples indicate that the crystals are calcite. The first presence of these CCCs was noticed in December 2018 in a pool with a highly degraded ice cover. In Spring 2019, the same pool was covered by a new ice layer and some comuños were present, one of them hanging from the ice cover, as well as in a nearby pool. These observations, and the study of stable isotopes, will help to refine the pool model for the formation of CCC_{coarse}.

Unprecedented cave ice melting over the last 6100 years in Southern Europe

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Current global warming is the main cause of the observed dramatic decline in glaciated surface and permafrost extension worldwide. Less is known, however, about the impact on ice caves, cryospheric environments poorly studied but highly exposed to environmental changes. A294 ice cave is located in the Central Pyrenees (Cotiella massif), and hosts an ice deposit (firn) which spans from 6100 to 1880 cal. years BP. This exceptional deposit is suffering a dramatic ice decline in recent years, and its imminent demise is feared. The ice body stratigraphy comprises detrital layers (unconformities) representing decadal-scale ablation periods. Three of these unconformities, however, represent periods with low ice accumulation at 5515 - 4945, 4250 - 3810 and 3155 - 2450 cal. years BP related to drier and maybe warmer winters. Information about current conditions in the cave is extensive and evidence a dramatic ice lost which is unique in the long history of this ice deposit. Thus, twelve years of cave monitoring, historical cave surveys, photographs, and ice measurements indicate a continuous retreat of the ice body (ca. 8 - 140 cm a^{-1}), and a rise of the cave air temperature (ca. 1-1.5°C). The increase in cave air temperature is related to the increase of winter temperatures, which controls the cave temperature during the open phase, while during the closed phase it depends on the previous open phase and the heat transfer via drip water. Thus, less waters freezes every year, triggering a fast ice retreat which is also favoured by a continuous decrease in snowfalls. Our current observations clearly manifest that a phase of drastic melting conditions, as the one evidenced currently, is absent in the ice stratigraphy. If a similar melting phase/s than the one the deposit is experiencing today would have occurred in the past, the ice stratigraphy would have shown truncated strata and important high angular unconformities due to the melting and the accommodation of the following snow aggradation phase/s. These observations in conjunction with regional palaeoclimate data indicate that the ice decline in the A294 ice cave is unprecedented in the context of the last six millennia.

A glacial-geologic vantage on MIS-2–1 tropical climate variability from the Colombian Andes

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As the primary source of energy, water vapour, and latent heat export for Earth's atmosphere, the tropics dominate our climate system both on long and short timescales. Recent research even suggests a driving role for the tropics in the abrupt climatic shifts that characterised the Late Pleistocene and which, potentially, represent Earth's preferred mode of changing climatic state. Therefore, tropical mountain glaciers and geologic records of former glacial change afford a unique opportunity for exploring the timing and magnitude of past climatic variability and thus testing new hypotheses for global change. Yet high-quality glacial-geologic records from low-latitude settings remain relatively scarce and consensus on how the planet's single largest climate zone contributes to global climate has yet to emerge. To help address this shortcoming, we present a new glacial-geologic record from the Sierra Nevada del Cocuy, Colombian Andes (6°N), spanning MIS-2 and the early Holocene and resolved with cosmogenic ^{10}Be surface-exposure dating. Coupled with glacier-climate modelling, we also use this record to assess the potential influence of topography on glaciers' response to climate.

Well-preserved moraine landforms in the Lagunillas and Bocatoma valleys describe a Late Pleistocene mountain glacier system that, at its maximum extent, terminated at ~3600 m elevation, approximately 700 m below the local Little Ice Age limit. Beryllium-10 ages constrain the outer complex to the period spanning the Last Glacial Maximum (LGM: ~30–19 ka) and also reveal the fine structure of glacier–and therefore climate–fluctuations during the LGM. Inboard of the LGM, our record constrains not only the onset of and protracted retreat of tropical ice during Termination 1, but also the timing of multiple, brief readvance events that punctuated overall warming. In both Lagunillas and Bocatoma, a longer and more pronounced readvance occurred during the Lateglacial, yet clear discrepancies in the relative timing of these events potentially reveals the influence on mass balance of topography. More broadly, comparison of the glacier-inferred Cocuy climate record to other datasets generated via the same methodology, both within and beyond the tropics, has revealed key similarities and important disparities in the timing and nature of natural climate variability.

The sedimentology of Austria's dying glaciers

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The dramatic shrinkage of Austria‘s glaciers records unprecedented change. However, the sedimentary record left by downwasting or retreating Alpine glaciers provides a potential opportunity to better understand this process, and also to inform our understanding of the complexity of Pleistocene glacial deposits preserved in mountainous landscapes. Drawing on examples from three glacier forefields, it is shown that dying glaciers in Austria are associated with unique landsystems and sedimentary facies. For the Pasterze Glacier, disconnections from the accumulation area, rapid elevation loss at the snout and flow stagnation are characteristic, and a complex delta system is observed building out on a large lake at the top of the buried, stagnant ice at the margin. Observations from 2018 and 2021 show extensive cannibalisation and lobe switching interpreted to result from downwasting of the underlying ice. At the flanks of the Gepatschferner in the Ötztal Alps, a 10 m thick subglacial till blanket was exposed in 2021. This till blanket, which may have partly supported the ice margin before a major phase of downwasting by July 2022, is mantled by a series of small (50 cm high, 50cm wide, 5 m long) ice parallel ridges. Such ridges are ice-margin parallel and are also very well expressed in front of small glaciers in Pitztal. These are tentatively interpreted as passive fills to crevasses (i.e. material sliding of the glacier surface into marginal crevasses). Detailed textural investigation of these structures, coupled with ongoing detailed mapping at multiple scales, is warranted to understand the significance that this association of facies holds in writing the last chapters of Alpine glaciers.

Glacial Lake Speight: A tale of two hypotheses

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Palaeo-lake shorelines are well-preserved on several voluminous fans in the middle Waimakariri River catchment in the Southern Alps of New Zealand. These shorelines are a key piece of evidence in the concept of 'Glacial Lake Speight', originally interpreted in the late 1950s to have temporarily occupied the valley during deglaciation from the local Last Glacial Maximum ice extent. The existence of this former lake is well-known within the local Quaternary community, and it is often considered a type-site for river-blocking events and consequent lacustrine development. Despite this, its proposed mechanism of damming remains under scrutiny by two competing hypotheses. The original view postulates that terminal moraine and debris-covered stagnant ice dammed the lake, which persisted for hundreds of years. However, the relative age of landforms in the valley conflicts with this interpretation. Surface stratigraphy reveals that the lake must have been younger than previously proposed because the fans, upon which the shorelines are preserved, would not have survived glacial occupation of the valley. An alternative hypothesis for the river-blocking is a co-seismically-triggered landslide, for there is an abundance of scars on surrounding hillslopes and the proposed damming site lies in close proximity to several active faults. Constraining the age of this lake is therefore critical to determine the valley-damming mechanism and to obtain a better understanding of landscape development in the region. In our new study, the detailed evolution of valley-damming is reconstructed from observed sediment sequences and optically stimulated luminescence dating. With carefully targeted chronological data from the lake shorelines, we confirm that the damming was likely triggered by changes in the extent and thickness of glacial ice and that the original interpretation as a glacial lake still stands. The discrepancy between geomorphological evidence and chronological control is still apparent however, and for this interpretation to hold true, it requires contemporaneous fan building and shoreline erosion. Our re-evaluation suggests that perhaps the hypotheses are not mutually exclusive after all, but that it is possible for a seismic event to have occurred during or shortly after deglaciation allowing post-glacial fan activity to fit within the geochronological sequence of events.

Timing of Glacial Extents on Cerro Chirripó during Termination I using 10Be and 3He Surface Exposure Dating

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The role of the tropics in past climate changes including the last glacial-interglacial transition (known as Termination 1) is poorly understood. Here we aim to improve the understanding of past tropical temperature change during Termination 1 using the extents of mountain glaciers in the inner humid tropics (~10 degrees N to 10 degrees S latitude), where glacier mass balance is sensitive to changes in temperature. We present new data on the timing of the Last Glacial Maximum extents on Cerro Chirrpó (3820 m asl, ~ 9.48 N, 83.49 W) in Cordillera de Talamanca in Costa Rica. We apply ^{10}Be and ^{3}He surface exposure dating of glacial moraines and glaciated bedrock. Our results thus far show that glaciers in Valle las Morrenas and Valle Talari near Cerro Chirrpó reached their maximum extents at ~21-19 ka. Subsequently, glaciers receded rapidly, with high-elevation bedrock surfaces near the heads of the valleys indicating ice-free conditions by ~17.5 ka. We compare these results to other records of tropical glacial extents during Termination 1 including those in South America and East Africa. This comparison suggests a consistent pattern of tropical terrestrial cooling during the global Last Glacial Maximum (~26-19 ka) followed by rapid warming at ~19-17.5 ka.

Age of the oldest Quaternary sediments in the northern Swiss Alpine foreland

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The northern Alpine foreland was extensively glaciated and witnessed multiple phases of alternating deposition and incision within the Middle and Early Pleistocene. These processes have created the present landscape with elevated plateaus separated by deeply incised overdeepened valleys. On top of these plateaus can be found the oldest Quaternary glaciofluvial sediments in Switzerland called Deckenschotter (DS) – traditionally divided into two phases of formation: Higher Deckenschotter (HDS) and Lower Deckenschotter (TDS). The stratigraphic relationship of HDS and TDS is inverted and their elevations differ by approx. 100-150 m. The time of their deposition is important for understanding long-term landscape evolution of the northern Alpine foreland. We aim to reconstruct the chronology of the alternating phases of deposition and incision of the Deckenschotter gravel units. Our focus is placed on Deckenschotter deposits outcropping at several locations in northern Switzerland, where we selected two HDS (Tromsberg and Feusi) as well as four TDS (Iberig, Hungerbol, Cholfirst and Schwändihalden) sites. In this study we implement the isochron-burial dating technique with the pair of cosmogenic nuclides, ^{26}Al and ^{10}Be, to date the Deckenschotter sediments (Granger, 2014). Furthermore, we utilize P-PINI (Particle Pathway Inversion of Nuclide Inventories), a new burial-dating model proposed by Knudsen et al. (2020) that applies a source-to-sink approach to further examine and refine the question of the timing of deposition of the various Deckenschotter units. However, due to a lack of clear topographic channel constraints and overriding by subsequent glaciers at some sites, terrace correlation is not a straightforward task. Furthermore, recent dating results fired a debate on DS correlations. Therefore, we combine these time constraints with results from a GIS-based morphostratigraphic analysis of the glaciofluvial plateaus by testing paleofluvial pathways and related terrace correlation. This contributes to better understanding of the spatial and topographic relationships between the several Deckenschotter deposits as an aid to deciphering the Early to Middle Pleistocene evolution of the Alpine foreland.

Ice Memory Italian drilling: a research project to collect heritage ice cores from Alps, Apennines and Arctic region

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The last IPCC special report on the cryosphere states that the glaciers will lose substantial mass by the end of the century, all over the word. Glaciers decline is going to cause the loss of climatic information stored in the ice layers. It is therefore strongly urgent to take action to preserve this information. Ice Memory (IM) is an international research project that aims to drill ice cores from mountain glaciers from all over the world, to characterize their climatic and environmental records and store them in the coldest place in the world: Antarctica.
The Italian team of Ice Memory is working to collect six ice cores from ice bodies with different characteristics: a) two glaciers located over 4000 m asl on Grand Combin (GC) and on Mt. Rosa (RS) (Pennines Alps); b) the Marmolada Glacier (MR), which is the largest glacier of the Dolomites, located below 3000 m slm; c) the Montasio Glacier (MS), which is the lowest glacier of the Italian Alps, located at around 1900 m slm on the Giulian Alps; d) the Calderone glacieret (CL), which is the southernmost European ice body, located in the middle of Appennines at around 2700 m asl; and e) Holthedlafonna glacier (HO) which is a large glacier in the north part of Svalbard Islands at 1100 m. HO glacier area is equal to 600 km2, MR, MS, and CL are characterized by glacier area lower than 1.5 km2, whereas MS and CL are smaller than 0.05 km2. To date, three of the six missions have been accomplished on GC, RS and CL. The drilling survey on HO, MR and MS are scheduled for 2023 and 2024.
Although the presence of cold firn is an essential characteristic to preserve climate information, could low altitude and smaller ice bodies give us useful information about past climate? The challenge is to collect these samples before their complete disappearance, projected in the next few decades. For these reasons, IM represents the last chance to secure the information stored in these ice bodies.

Heavy Mineral Assemblages Indicating Dynamic Sediment Source of the Assam Basin in Response to Early Uplift Stages of the Eastern Himalayas

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Sedimentary rocks preserve the record of paleoenvironmental and paleotectonic conditions as the constituting sediments develop in close relation with the prevailing climatic conditions and the source rock type. In this study, we used the integrated approach of heavy mineral assemblages and the petrographic analysis to understand the temporally changing sediment source that fed the Assam Basin, India, during the early uplift stages of the eastern Himalayas.

The early upliftment and denudational history of the eastern Himalayas are recorded in the Oligocene siliciclastic sediments of the Assam Basin, which can be revealed by sandstone modal analysis and heavy mineral distributions. The Oligocene Barail Group exposed in the Digboi-Margherita area in the Assam is thick (~5 km), deposited mainly in brackish water to deltaic environments primarily consisting of the fine to medium-grained sandstones. The Barail Group constitutes three distinct formations: Naogaon ($Qt_{69}F_6L_{25}$), Baragolai ($Qt_{66}F_{12}L_{22}$), and Tikak Parbat ($Qt_{82}F_4L_{14}$) from old to young, respectively. We collected 16 representative sandstone samples from different formations in the Barail Group and separated heavy minerals using heavy liquid (tetrabromoethane) for quantitative analysis. The assemblages of heavy minerals are mainly dominated by opaque minerals (around 80 wt. percent), along with non-opaque varieties including ultra-stable heavy minerals (zircon, tourmaline, and rutile), garnet, apatite, epidote, hornblende, muscovite, topaz, chlorite, chloritoid, and prehnite. The concentration and diversity of heavy minerals increase up section, suggesting changing sediment source type. Total heavy mineral concentrations vary from negligible to up to 1.5 wt. percent in entire succession with the minimum value in lowermost Naogaon Formation and the maximum value in uppermost Tikak Parbat Formation. Although the concentration of heavy minerals increases with time, the ZTR index decreases from 20% in Naogaon to 3.65% in Tikak Parbat Formation, indicating decreasing compositional maturity of heavy mineral assemblages with time. There is also an increase in the concentration of garnet, staurolite, andalusite and a decrease in the concentration of chlorite, chloritoid, prehnite, epidote in the up-section, suggesting a change in the source type from lower to intermediate grade metamorphic rocks. Further understanding of heavy mineral chemistry can unveil the sediment source information at a higher resolution.

Europe’s Lost Frontiers: New Perspectives, New Insights.

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Europe’s Lost Frontiers was the largest, directed archaeological research project undertaken in Europe to investigate the inundated landscapes of the Early Holocene North Sea – the area frequently referred to as ‘Doggerland’. Funded through a European Research Council Advanced Grant (project number 670518), the project ran from 2015 to 2021, and straddled both Brexit and the onset of the Covid pandemic. Despite suffering the curse of interesting times, more than 30 academics collaborated within the project, representing institutions spread geographically from Ireland to China. A vast area of the seabed was mapped, and multiple ship expeditions were launched to retrieve sediment cores from the valleys of the lost prehistoric landscapes of the North Sea. This data has now been analysed to provide evidence of how the land was transformed in the face of climate change and rising sea levels.

This presentation will present some of the results of the Europe’s Lost Frontiers project (Gaffney et al. 2022), that demonstrate that the utilisation of spatially extensive data allows the recovery of information pertaining to the actual Mesolithic landscape of the North Sea and that extensive mapping of the region is now possible. This information not only reveals the diversity of this landscape but will suggest that the project will provide benchmark data for future research on the environmental and cultural heritage of Doggerland. This is increasingly important as it is clear that contemporary climate change, and the rush for green energy, is pushing development within the North Sea at an unprecedented rate. In the face of such change, it will be argued that it is vital that academics, developers and curators work together to assist green development, but also to continue exploration of Europe’s largest and best-preserved prehistoric landscape.

Investigating the Holocene storm flood history of East Frisia – geomorphological studies near Dornum (North Sea coast, Germany)

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Since the end of the last Ice Age, the landscape of East Frisia (Lower Saxony, Germany) has been shaped by a sharp rise in sea level and a resulting loss of land. Storm surges have repeatedly flooded populated areas, especially since the Middle Ages. Man tried to counteract this development, for example by building dykes.

The data and results presented here originate from the marsh near Dornum in East Frisia, located inland of the Accumer Ee tidal inlet. Due to this location, the study area was particularly exposed to storm surges in the past. Between the barrier islands of Baltrum and Langeoog, the water could flow towards the coast unhindered. A port near the present-day Dornum was first mentioned in AD 1289. During the 1st Grote Mandrenke (or St. Marcellus' flood) in AD 1362, the dyke was breached and a bay between Dornum and Westeraccum was created. Several attempts to repair the dyke failed. Efforts to close the bay succeeded almost 100 years later, largely along the dyke line from before AD 1300.

It can be assumed that past storm surges have left their mark at the research site. Geophysical investigations and vibracoring at selected locations were carried out with the aim to find evidence of past storm surges and to reconstruct the landscape history of the region. Vibracores ACC 1A and ACC 3A as well as the results of geophysical investigations document several Holocene extreme events. Geochemical and microfauna analyses support these results, radiocarbon dating was used for establishing a geochronostratigraphy.

Let's go to the red mountain – Preliminary results of and future plans for Late Pleistocene - Early Holocene palaeolandscape reconstruction off the Heligoland coast

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In a vast and dynamic Late Glacial landscape in the southeastern North Sea, Heligoland must have been of immense importance. It was a landmark, vantage point and source region of unique red flint, which was extracted there and transported into the present inland since the Late Palaeolithic. The reconstruction of Late Palaeolithic living and migration conditions in not-yet flooded areas of the North Sea, especially around Heligoland, is one of the central unresolved questions of today's Stone Age research for northern Central Europe.

High-resolution sediment echo sounding data has been acquired near Heligoland during cruises AL496, AL511 and MSM98/2. The preliminary analysis of this data reveals a high density of shallow channels that exhibit (apparent) widths of 200 m to 600 m. Our first results suggest an extensive Late Pleistocene - Early Holocene drainage pattern. We aim to reconstruct this drainage pattern for the Heligoland area, as it will allow us to determine probable locations of hunter-gatherer settlements and related migration paths on land and water through the period in question.

However, as the line spacing of available sediment echosounding profiles is not close enough with respect to target size, correlating channels and other landforms between profiles is not always possible. Furthermore, the extension of the channel network to Heligoland is yet unknown. Future fieldwork (German Research Foundation cruise TRAPA, planning pending) is intended to remedy this. We plan to map a 20x23 km wide area northeast of Heligoland with a Teledyne Parasound system at very high lateral resolution. Ground truthing and dating of land surfaces will be achieved by means of a 6 m Vibrocorer.

Is this waterscape connected to the present river Eider and/or the tidal stream Heverstrom? Does the channel network continue towards Heligoland and thus serve to guide reindeer herds and their hunters past the red massif? How dynamic is this palaeolandscape likely to have been? Are the courses of major rivers stable, or do they change on a shorter than millennial time scale? So far, there are lots of questions and the promise of answers once we venture at sea.

Analysis of a buried post-Eemian erosional feature in the Southern North Sea

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The southern North Sea has been significantly affected by glacial and interglacial cycles during the Middle and Late Pleistocene. The offshore stratigraphic record can be used to understand the regional response to these climatic changes and reconstruct the Quaternary palaeo-landscape evolution of the area.
During the Eemian Interglacial (MIS 5e) and the Weichselian Early Pleniglacial (MIS 4) periods, the regional climate underwent significant changes and sea level fluctuated considerably. The global sea-level record illustrates a period of rapidly rising sea level towards the Eemian highstand, reaching values close to the present, followed by a drop of 40-50m during the Early Pleniglacial lowstand. During the Eemian- Weichselian transition, a widespread 5-20m thick unit composed of clay-rich, brackish-marine sediments was deposited across the southern North Sea. This deposit is known as the *Brown Bank Formation (BNB)* or *Brown Bank Member* in the British and Dutch sectors, respectively. Although it is easily identifiable on seismic profiles as a unit composed of (sub)parallel reflectors, its chronology and depositional environment remain poorly defined.
For this study, high-resolution seismic data and sediment cores were collected in 2022 from the wider area of the North Axial Channel, a major NS-oriented palaeo-river system. The seismic data reveal the presence of a buried and infilled channel-like feature that locally incises the older sediments of the BNB. This NS-oriented feature has a total length of more than 20km, a width of up to ~1.5km, and a max. depth of ~25m below the seafloor; core data show the infill consists of fine-grained sediments. The geomorphology of the channel and sedimentary infill pattern imply a period of extensive erosion of the BNB followed by rapid infilling with younger sediments. We aim to examine the newly acquired datasets to better understand (a) the processes that shaped the erosional surface within the BNB, (b) the genesis, age, and morphology of the enigmatic channel, and (c) the depositional environment and processes in the region. Any information derived from this study will be a valuable contribution to understanding and reconstructing the stratigraphy, sedimentary architecture, and depositional history of the southern North Sea during the late Quaternary.

In search of seismic and sedimentary evidence for proglacial North Sea lakes: Insights into their distribution and role during the Elsterian and Saalian glaciations

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During the Middle and Late Pleistocene, ice sheets occupied parts of the North Sea during three major glaciations, the Elsterian (MIS 12), the Saalian (MIS 10-6) and the Weichselian (MIS 4-2). The exact limits of these expanded ice sheets and the dynamics and chronology of the expansions are, however, still a point of discussion. Nevertheless, most offshore studies support the idea of the presence of proglacial lakes in some form and at some point in time in front of these ice sheets. Solid geomorphological and sedimentological indications for the presence of these lakes are, however, scarce and evidence is mostly circumstantial. The existence of an Elsterian proglacial lake is e.g. used in the argument that glacial outburst floods created the erosional features preserved in the Dover Strait.

As part of the WALDO project ("Where are All the (proglacial) Lake seDiments in the NOrth Sea Basin?"), this project aims to test the hypothesis that proglacial lakes were important landscape features in the southern North Sea during the Elsterian, Saalian and Weichselian glacial periods, based on the analysis and interpretation of marine geophysical and geological data. In the framework of this project, two surveys with RV Belgica have been conducted, during which high-resolution geophysical data (multibeam bathymetry and backscatter, acoustic and seismic data) have been acquired in parts of the southern North Sea where proglacial lakes have been inferred to have existed in previous studies. The first data presented here are retrieved from the Southern Bight area and are used to update the lithostratigraphic framework and regional palaeo-geography, in order to gain a better understanding of the landscape evolution during the Elsterian and Saalian glacial periods.

Spatial variability in isotopic composition of surface snow along the East Antarctic International Ice Sheet Traverse (EAIIST)

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The isotopic signal of oxygen and hydrogen, archived in the Antarctic ice sheet through snow precipitation, is an important proxy of climatic conditions. This signal depends on several parameters such as local temperature, climatic conditions in the moisture source areas and air mass pathways. Moreover, the isotopic composition may be affected by spatial variability induced by the interactions of the snow surface with the overlying atmosphere along the direction of the prevailing winds. In regions where the snow accumulation is very low, interactions between the atmosphere and the snow surface could modify the pristine signal through isotopic exchanges, sublimation processes and mechanical mixing originated from wind action.

The EAIIST (East Antarctic International Ice Sheet Traverse) traverse, which took place during the 2019-2020 Antarctic field season, starting from Concordia Station towards the South Pole, provides a perfect path of study. Along the EAIIST traverse, areas with homogeneous accumulation rates can be compared to areas influenced by wind scouring and mega-dunes formation. Extremely low accumulation and wind-surface snow interaction observed in these areas could be representative of glacial period conditions in the Antarctic Plateau.

Here we present the isotopic composition (dD and d18O) of surface (a few cm of depth), bulk (1 m depth) and snow pit (2 m depth) samples along the EAIIST traverse to evaluate the parameters explaining the spatial variability of this proxy. The dD, d18O and the deuterium excess will be evaluated with respect to geographical features (elevation, latitude, distance from the coast, slope) and climatic conditions (temperature, accumulation, wind speed and direction). Wind action is expected to play a major role in explaining the isotopic spatial variability in these areas.

Understanding the spatial variability in the deposition process, which strongly decreases the ratio between signal and noise, is essential to better interpret high-resolution isotopic profiles from firn and ice cores, collected along the EAIIST traverse, which will be analyzed soon.

The anthropogenic footprint through a high-resolution analysis of trace organic compounds in an Antarctic ice core

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This work focuses on the reconstruction of the anthropogenic fingerprint over the last 150 years through the analysis of organic compounds preserved in Antarctic ice. The ice core (length: 50 m; diameter: 100 mm) was retrieved at GV7 during the 2013/14 austral summer campaign. This is an ideal archive for studying the "Great Acceleration" since it spans the last 150 years and it was extracted in a highly significant site. The GV7 site (70°41'S, 158°51' E, 1950 m a.s.l.) presents a high snow accumulation rate (241 ± 13 mm we yr^{-1}) which ensures high temporal resolution. Indeed, this feature is not easily found in archives covering such a recent period and it is crucial for performing high-resolution analyses on trace organic compounds that require relatively large amounts of matrix.

In the last decades, several pollutants have been subject to international bans and restrictions aimed at reducing their industrial production due to their high toxicity and persistence in the environment. As a result, limitations on one compound have led to increased industrial emissions of other pollutants. The recently developed multi-proxy analytical method for snow and ice samples employed in this work enables to detect trends in well-established and emerging pollutants preserved in the ice resulting from successive international bans on several POPs. Furthermore, volatile personal care products can provide information about changes in household habits. Specifically, fragrances from domestic sources have exponentially increased over the past 50 years. Therefore, the unprecedent high-resolution study of these substances in Antarctic ice enables one to recognize the evolution of single compounds over time, in response to international agreements and social changes. Thus, the anthropogenic signal is mainly described by semi-volatile and highly persistent tracers which are carried over long distances in the atmosphere to the polar regions, where they accumulate as result of cold condensation processes.

Trace organic compounds were determined by using solid-phase extraction (SPE) combined with gas chromatography coupled to triple quadrupole mass spectrometry (GC-MS/MS). The samples preparation was carried out entirely in a stainless-steel cleanroom to minimize organic contamination, achieve low detection limits and increase the analytical signal.

Deciphering the Oxidizing Capacity of the PAST atmosphere (ERC Doc-Past) by switching from elemental to molecular isotope ratios

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Atmospheric chemistry is an essential component of the functioning of the Earth's climate. It determines the atmospheric lifetime of most climatic agents impacting the nature and concentrations of aerosols, greenhouse gases, cloud formation. Determining how this chemical reactivity has evolved in the past is essential, both for evaluating chemistry-climate models (CCM) and for establishing future climate trajectories. The chemical activity of the atmosphere is driven by highly reactive atmospheric compounds that have a very short lifetime in the atmosphere. Because of this ephemeral nature, they are not archived in the paleoclimate record. Reconstructing this chemical activity over time remains a difficult exercise that has not been successful to date. Using ice cores, the multidisciplinary DOC-PAST project proposes to develop new tracers of this chemical activity by taking advantage of the revolution introduced by clumps and isotopic anomalies. The aim is to use a variety of ice cores covering all latitudes to highlight key elements of the chemical reactivity of the atmosphere. This poster will present the main hypothesis of the Doc-Past ERC as well as the strategy and new analytical means to reveals the past oxidation state of the atmosphere.

New chronology of EPICA Dome C (EDC) ice core over the last 800 ka using the Bayesian tool Paleochrono and new records of elemental and isotopic composition of air trapped in the core.

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To understand the phase relationships between external forcing and climate change, precise ice cores chronologies are crucial. However, dating ice cores is particular since they require two chronologies: one for the ice and one for the younger air trapped in bubbles. The EDC ice core covers the last 800 ka and was dated in the framework of AICC2012 chronology, established for five ice cores: EDC, EDML, NGRIP, VK and TALDICE using the following method. A sedimentation model is used to calculate prior age scales from a background scenario of three variables: snow accumulation, ice thinning and Lock-In-Depth, the lowest depth where air is locked in bubbles (LID). A Bayesian tool then statistically adjusts the age scales, and the three variables, so that they respect chronological observations (dated horizons, dated intervals, stratigraphic links between cores, ...). The AICC2012 chronology is associated with an uncertainty around 2,500 years, reaching 8,000 years at the bottom of the core mainly due to orbital dating uncertainty. Here, we present new data on EDC ice core reducing the new chronological uncertainty.

New data consist in: 1) additional absolute age constraints spanning the last 800 ka derived from radioisotopes (^{40}Ar, ^{81}Kr) measured in air trapped in EDC ice core, and 2) new orbital age constraints obtained by synchronising EDC ice core records with their orbital target. These records include the air isotopic composition ($\delta^{18}O_{atm}$, $\delta O_2/N_2$), recently measured at high-resolution over the last 800 ka, and the total air content (TAC) signal now spanning the entire core. Volcanic bipolar synchronisation provides additional stratigraphic links, relating EDC to other cores and reducing the uncertainty on recent periods. Finally, the estimation of the LID allows to connect ice and air timescales, therefore it is an essential ice core dating tool. Here, we present new information constraining the LID, including highly-resolved measurements of air isotopic composition ($\delta^{15}N$) and firn modelling estimates when data are missing. Then, the Bayesian dating tool Paleochrono is used to construct new air and ice chronologies over the last 800 ka. The associated uncertainty is of 1,700 years on average, mainly decreased over the last 650 ka.

"A new Hybrid Continuous Flow Analysis (CFA) system coupled with Fast Liquid Chromatography - Tandem Mass Spectrometry (FLC-MS/MS) for Biomass Burning (BB) tracers' analysis in ice cores. Applications for paleoclimatological characterizations."

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One of the main challenges the paleoclimatic scientific community is currently facing is represented by the achievement of high-resolution measurements for chemical markers in ice cores, while limiting time efforts for sample processing and analysis. Therefore, a new Continuous Flow Analysis (CFA) system has recently been realized at Ca' Foscari University of Venice, in collaboration with the CNR Institute of Polar Science (CNR-ISP). The novelty of this technology is allowing for on-line measurements of meltwater flow and the contemporary collection of samples for subsequent discrete analyses. Coupled with Fast Liquid Chromatography – tandem Mass Spectrometry (FLC-MS/MS) for continuous high-resolution measurements of organic markers in ice cores, the CFA is capable of 1 cm of spatial resolution. After optimizations, this approach has been applied to the quantification of specific biomass burning tracers, such as vanillic acid, syringic acid, and levoglucosan, obtaining one measurement every 30 s. To assess the robustness of the system with real samples, we tested the system using an alpine ice core. Together with organic compounds, insoluble dust particles and conductivity records can continuously be acquired, while the discrete samples collection from dedicated lines offers the opportunity to subsequently analyze trace and crustal elements, major ions and water stable isotopes.

Investigation of the in situ production of N2O in Antarctic ice cores using isotope analysis

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Nitrous oxide (N_2O) is a trace gas in the atmosphere involved in stratospheric ozone destruction, and a potent greenhouse gas whose concentration has varied substantially in the past. Ice cores represent the only direct paleo-atmospheric archive that would allow the reconstruction of the past N_2O atmospheric concentration over the last 800 000 years. However, such a long continuous record is still missing, as some sections of Antarctic ice cores corresponding to dust-rich glacial intervals are affected by *in situ* production of N_2O. These sections show elevated N_2O concentrations.
Using isotopic analysis, this study aims to identify the processes responsible for N_2O *in situ* production, in order to eventually correct the N_2O signal. We observe clear deviations of the nitrogen ($\delta^{15}N$) and oxygen ($\delta^{18}O$) isotopic composition of N_2O in glacial Antarctic ice affected by *in situ* production from the atmospheric values (as defined by the almost unaffected Talos Dome ice core record). The $\delta^{15}N(N_2O)$ signature of the *in situ* fraction becomes systematically more enriched with decreasing accumulation rate, while its $\delta^{18}O(N_2O)$ signature shows no systematic dependence on accumulation rate. Since nitrate (NO_3^-) shows the same enrichment with decreasing accumulation rate, NO_3^- could be the precursor for high $\delta^{15}N$ values of *in situ* N_2O at low accumulation sites. To test this hypothesis, we carried out joint measurements of $\delta^{15}N$ and $\delta^{18}O$ of N_2O and NO_3^- in samples from the EDC, EDML, and Talos Dome ice cores. The resulting $\delta^{15}N$ values of NO_3^- and *in situ* N_2O appear to be highly correlated with a slope of 0.5, whereas the $\delta^{18}O$ values show two distinct clusters for low and moderate accumulation sites. Our results support the hypothesis of a denitrification reaction with an oxygen isotopic exchange between the nitrite intermediate and water. However, the N isotopic data show that NO_3^- is probably not the only precursor and that one of the N atoms may originate from another nitrogenous compound. This investigation will be narrowed down by additional isotopic analyses and site preference measurement of ^{15}N in N_2O, which, by differentiating nitrification and denitrification, would allow to determine the reaction mechanism.

On the use of a new 800 ka Total Air Content record to improve the dating of the EPICA Dome C ice core

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Accurate absolute chronologies of ice cores are crucial to interpret paleoclimatic records and to decipher their relationship to external and internal forcings. The chronology of the deeper part of Antarctic ice cores is mainly constrained by orbital age markers inferred from tracers measured in air trapped in ice. In particular, age markers deduced from the alignment of the Total Air Content of the ice (TAC) on a local integrated summer insolation curve were used to constrain the AICC2012 chronology of the EPICA Dome C (EDC) ice core over the past 440 ka. However, a full understanding of the physical processes influencing TAC variations is still missing together with a quantitative estimate of the age uncertainties attached to TAC-based age makers.

Here, we present new TAC measurements on EDC at a ~2 ka resolution extending the published record back to 800 ka. First, we investigate the imprint of orbital periodicities in the 800 ka TAC record using spectral analyses. We identify that the last 500 ka of the record is characterised by a dominant period related to obliquity but its strength decreases significantly in the oldest part. Second, we investigate the most relevant orbital tuning target to infer age markers based on a comparison between the TAC record and a selection of local summer insolation curves, and our understanding of how the insolation signal could get imprinted in TAC. Third, we quantify the age errors attached to TAC-based markers considering sources of uncertainties related to (i) the choice of the orbital target, (i) the filtering band for TAC, (iii) the record alignment method and (iv) the loss of visual resemblance between variations in TAC and its orbital target. Age uncertainties vary from ~2 ka to more than 6 ka.

The comparison of a TAC-based chronology with the AICC2012 chronology over the last 600 ka suggests ages differences of 1.4 ka on average and they vary within the stated AICC2012 age uncertainties. Finally, we compare the TAC dating constraints with those deduced from O_2/N_2 and we discuss implications for a joint use of these orbital tools in order to date old ice.

New Zealand volcanic eruptions captured in Antarctic ice cores

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Changes in the Earth's climate and environment have been documented after historic volcanic eruptions, however, the magnitude of explosive eruptions in the geological record far exceeds those witnessed in modern history, by up to one hundred times. New Zealand provides an ideal opportunity to assess the impacts of huge volcanic eruptions on the climate and environment due to a number of large and well preserved large eruptions occurring over the last million years. Here we present tephra geochemical results of the Taupō (232 CE) and Oruanui (25.5 ka) eruptions recently identified in multiple Antarctic ice cores. The identification of ash from New Zealand eruptions in multiple ice core records will help refine ice core chronologies and provide insights into the regional and global environmental impacts of these huge volcanic eruptions. For example, the large ash plumes, rich in limiting micronutrients such as iron, likely covered vast areas of the Southern Ocean supplying bioavailable iron nutrients required for phytoplankton blooms and marine primary production; a process which converts atmospheric carbon dioxide into organic matter. We outline our plans to investigate iron fertilisation and the response of marine primary production in the Southern Ocean following the large explosive volcanic eruptions using novel ice core proxies.

Using ice core records to understand interannual-multidecadal patterns, trends and drivers of Antarctic Ice Sheet accumulation changes

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The Antarctic Ice Sheet (AIS) is currently losing mass. However, the causes of these changes are not fully understood and the rate and magnitude of future AIS mass loss remains highly uncertain. The extent of potential ice sheet mass loss offset by increases in future Antarctic precipitation is unclear. Rising near-surface atmospheric temperatures will cause an associated increase in the atmospheric moisture-holding capacity, resulting in increasing Antarctic precipitation and accumulation, however, the resultant amount of precipitation increase is uncertain.

Satellite records extend 40 years, but ice sheets respond to climate from seasonal to greater than centennial timescales, meaning hundreds of years of observational data are required to understand the physical processes driving AIS surface mass balance. Therefore, paleoclimate data is necessary to characterise variability and to differentiate between trends and variability in surface mass balance. This research addresses these critical gaps by characterising variability in surface mass balance changes in Antarctic ice core accumulation records over the past 2000 years. Ice cores provide annually resolved records of accumulation changes and climate signals dating back through recent centuries. This study utilises regional composites of ice core data, which provide a circum-Antarctic perspective. We use a formal statistical approach for detecting trend shifts, and find statistically significant changes in accumulation trends during and across both pre-industrial and post-industrial periods. Accumulation trend shifts in some regional composites align with periods of low solar activity, such as the East Antarctic Plateau. We find significant changes in accumulation trends in post-industrial periods across almost all regions of Antarctica, especially the Antarctic Peninsula. We decompose the accumulation records into different frequency components and explore the potential links to large-scale modes of variability. Our results highlight the possible emergence of an anthropogenic signal in Antarctic accumulation rates in the context of natural past variability from Antarctic ice cores. However, our findings are limited by the resolution and spatial availability of Antarctic data, highlighting the need for innovative analysis of high-resolution Antarctic accumulation, over both the palaeo and instrumental period, in order to better establish and constrain the signature of anthropogenic forcing across different AIS regions.

Laser Ablation – Cavity Ring Down Spectrometry: A new technique for water isotope measurements on ice cores

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The Beyond Epica – Oldest Ice Core (1.5 Myr) which is being drilled in Antarctica will be a valuable paleoclimate archive and the water isotopic signal imprinted in the ice core layers will be one of the most important parameters to be measured. The extremely thin nature of the deep ice core layers requires measurements at very high resolution together with high precision and accuracy. A novel and promising measurement technique, which is being developed, couples Laser Ablation (LA) with Cavity Ring Down Spectrometry (CRDS) aiming to obtain high quality measurements. Laser Ablation (LA) is used as a micro-destructive sampling method, which is important for using the minimum amount of the valuable ice core samples, and allows not only high spatial resolution, but also fast and direct transition from solid to gas phase, when appropriate laser systems are employed. Craters, created on ice after the laser ablation process, are to be characterized along with varying laser parameters for the optimization of the controlling factors which lead to efficient LA sampling. Furthermore, designing an ablation chamber and a transfer line with the optimal shape and size is crucial for collecting the ablated material which should reach the high precision CRDS analyzer with minimum delivery disturbance.

Characterisation of insoluble particles in the EastGRIP ice core with the single particle extinction and scattering method (SPES)

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Ice cores contain information about past climatic conditions, such as the composition of the atmosphere. Aerosols, including insoluble particles, are deposited on the ice sheets and preserved in the ice. Analysing these particles provides the information needed to reconstruct past changes, for example, in circulation patterns and radiative transfer. Changes in the source regions of the aerosols, transport, and deposition mechanisms are reflected in alterations in the concentration, size distribution, and mineralogy of the particles.

To quantify the past changes in concentration and properties of insoluble particles, the Classizer One instrument, which is based on the novel single particle extinction and scattering (SPES) method, has been incorporated into the continuous flow analysis set-up in Bern. Previously available continuous particle sizing methods have typical lower detection limits of around 1 µm. However, the peak in the number size distribution of dust particles in ice cores is expected to be below 1 µm. Thus, while most of the mass of mineral dust could be observed, the majority of the particles could not. The SPES method allows for high-resolution, continuous, and simultaneous measurements of particle concentration, diameter, and refractive index in the size range of 0.2 to 2 µm. Therefore, its measurement range covers the maximum of the number size distribution.

The instrument was used to characterise particles in the EastGRIP ice core from 8000 to 16000 years b2k, covering the Younger Dryas (YD) to Holocene transition. We observe a decrease in number concentration from $2.7 \cdot 10^6$ ml^{-1} in the first half of the YD to $1.1 \cdot 10^6$ ml^{-1} in the second half, while the mean diameter increases over the course of the YD. This is followed by an abrupt decrease in the concentration by a factor 6 and a drop of approximately 80 nm in mean diameter at the transition to the Holocene. Previous studies have shown that the majority of dust particles originates from the East Asian deserts in the glacial. While the concentration and size distribution exhibit sudden changes, the refractive index increases gradually by 0.2, suggesting a long-term trend in the mineralogy, hence the relative contributions of different dust source regions.

Recent Antarctic sea ice variability in the context of the longer term records: Extending the Law Dome MSA sea ice proxy record to 2020.

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Antarctic sea ice plays multiple crucial roles in the Earth system, and understanding the long term (centennial-scale) trends (variability and change) in its coverage is crucial to the interpretation and attribution of observed rapid fluctuations (increases and decreases) in Antarctic sea ice extent (SIE). Ice core records have been used as an important proxy for past SIE around Antarctica prior to the satellite era, by extending the short-term satellite record back hundreds of years. One of the first studies to correlate ice core data with modern satellite SIE records used the ice core from Law Dome (East Antarctica) and was based on Methanesulphonic acid (MSA), which relates to primary productivity in the sea ice zone, and multiple other regional studies have followed. Here, we present an update to our 2003 study by extending the Law Dome record with MSA data up to 2020, and investigate the recent changes in Antarctic sea ice coverage in the context of the longer proxy record (back to the 1840s). We also extend the proxy calibration period using old Nimbus I satellite information from the mid-1960s to the mid-1970s

36Cl as a dating tool for deep ice

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The $^{10}Be/^{36}Cl$ ratio has the potential to be a dating tool for old ice, as it decays with a combined half-life of 3.84 * 10^5 years and is thought to be independent of production and dilution effects affecting the individual radionuclide concentrations in ice cores. Chlorine, however, suffers from post-depositional loss at low accumulation sites in Antarctica, which interferes with the decay signal and complicates dating. Comparisons of the $^{10}Be/^{36}Cl$ ratio from Little Dome C, the new Beyond EPICA Oldest Ice Core drilling site, with sea-salt chlorine and previous research suggest that little to no chlorine loss occurs during glacial times. The $^{10}Be/^{36}Cl$ ratio was therefore measured in ice from several glacial periods covered by the EPICA Dome C ice core Antarctica to test its potential as a dating method, with the oldest sample reaching back 746,000 years in time. We will discuss to which extent the measured $^{10}Be/^{36}Cl$ values show a decay signal and assess how unexplained variations diminish the accuracy and precision of the $^{10}Be/^{36}Cl$ dating method. While the selected samples are thought not to have suffered a major chlorine loss, possible additional interferences are likely the result of changes in climatic conditions and will be the focus of future research in order to correct for these changes and, therefore, improve the accuracy and precision of the $^{10}Be/^{36}Cl$ dating method.

Holocene sea ice variability in the Arctic: exploring diatoms in the ReCAP ice core as a new proxy

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The Arctic is warming faster than the global mean affecting the ocean, the cryosphere and arctic ecosystems. Furthermore, the decreasing sea ice is affecting the climate system on both a regional and global scale, possibly pushing the state of the climate into irreversible changes and undermining unique sea-ice dependent species. Understanding sea ice dynamics at high latitudes is, therefore, crucial in terms of better predicting future climate scenarios. Several Arctic sea ice proxies are routinely used based on marine sediment records (e.g. the lipid biomarker IP25, diatoms, and dinoflagellate cysts) and land ice cores (Bromine enrichment (Br_{enr}), Sodium (Na^+) and methanesulphonic acid (MSA)). However, as all proxies, they have some limitations. Here we aim to investigate if marine diatoms from land ice cores can be utilised to reconstruct past sea ice changes. With this goal, we analysed samples from the 584 m ReCAP ice core from Renland, East Greenland, which has a well-resolved Holocene. Here we present results on diatoms recovered from the ReCAP ice core, and discuss their potential as a sea ice proxy for the Northern Atlantic and Nordic seas. Furthermore, we evaluate how these relate to more established sea ice proxies from ice cores such as Na^+ and Br_{enr} and how our findings align with broader patterns of Holocene climate variability.

A 10-year record of the isotopic composition of precipitation at Concordia station, East Antarctica

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The atmospheric dynamics determining the isotopic composition of precipitation on the Antarctic Plateau are still under investigation.

At Concordia station, East Antarctica, daily precipitation has been continuously collected on raised surfaces (height: 1 m) placed in a clean area, about 800 m from the station. Samples have been analyzed for $\delta^{18}O$, δD, and deuterium excess (d). The on-going monitoring of precipitation isotopic composition represents a unique record in inland Antarctica.

Surface temperature (T_{2m}) from the Dome C Automatic Weather Station of the Italian National Antarctic Research Program (PNRA) was correlated with isotopic data of precipitation collected from 2008 to 2017, in order to better understand the relationship between local temperature and the isotopic signal of precipitation. A robust positive correlation between $\delta^{18}O$ and δD of precipitation and T_{2m} is observed when using both daily and monthly-averaged data. $\delta^{18}O$ and δD of precipitation were also compared to the simulation from the isotope-enabled atmospheric general circulation models ECHAM5-wiso and ECHAM6-wiso, with the most recent version showing a significant improvement.

The spatial deposition of volcanic sulphate in Antarctica over the past 2000 years

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The sulphate [SO_4^{2-}] records from deep ice cores have been invaluable in reconstructing the earths volcanic history over a range of timescales. Large volcanic eruptions inject sulphur into the stratosphere, producing near-synchronous deposition of sulphate in Antarctic and Greenland ice cores. Key studies linking bi-polar sulphate records have greatly improved our understanding of the frequency of large volcanic eruptions, and the impact on global climate. They also provide an important reference horizon to date and synchronise Antarctic ice core chronologies. However, most studies have been based on a limited number of deep ice cores, predominantly from high elevation and inland sites.

Here we present a new compilation of sulphate records from 103 Antarctic ice cores spanning all, or part, of the last 2000 years. The compilation includes records from both continental and lower elevation, coastal sites. The improved geographical coverage allows us to explore the spatial variability of sulphate deposition, demonstrating key differences in the magnitude of several known eruptions. Despite the higher background of biogenic sulphate at coastal sites, they provide a valuable record of tropospheric transport from more proximal eruptions. Enabling us to explore the frequency and magnitude of lesser studied Southern Hemisphere, sub-Antarctic, and Antarctic eruptions over the past 2000 years.

Ice core fatty acids as novel tracers of Southern Ocean sea ice change

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Satellite observations expose an increasingly complex picture of sea ice change around Antarctica: steady increases in sea ice extent between 1979 and 2014 have since been undermined by a series of unprecedented lows. Models have failed to reproduce these trends, partly because they rely on a 44-year long observational record that may be too short to capture the full range of natural variability. Proxy reconstructions of sea ice change covering the decades preceding the satellite era are essential to place the observed trends in the context of longer-term climate variability.

A range of biogenic, isotopic and geochemical sea ice tracers from Antarctic ice cores have been developed so far, yet each of these has its limitations. Additional sea ice tracers are needed so that each proxy can be tested against a suite of others, and more reliable sea ice reconstructions can be developed for new Southern Ocean sectors.

Here, we present work to develop fatty acids (FAs) as novel organic sea ice tracers. FAs originate from the same sea ice-edge algal blooms as the commonly used sea ice proxy MSA, but their structural diversity and algal-taxonomic specificity yields potential for a greater depth of sea ice climatic information. Yet, determining their concentration in polar ice is challenging owing to their low (ppb-ppt) concentrations. So far, only one study has analysed FAs at high resolution in an Antarctic ice core, revealing strong positive correlations between the FA oleic acid (C18:1) and nearby winter sea ice extent.

This study uses high-resolution liquid chromatography-mass spectrometry to analyse fatty acids archived at trace (ppt) levels in a 12-m long ice core from Peter I Island (Bellingshausen Sea). The data are compared with satellite observations of regional sea ice change, and with a range of other sea ice proxies measured from Peter I and nearby cores. The efficacy of fatty acids as novel tracers of past sea ice variability in the Bellingshausen Sea is evaluated.

Stratigraphic architecture of the Isarco-Pusteria valley junction (European Alps) showing the interaction between two major alpine glaciers during the Late Pleistocene

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The European Alps were composed of a complex network of valley glaciers during the Pleistocene, especially during the Last Glacial Maximum (LGM). The inner catchment of the Adige system is the largest of the southern side of the Alps; it is characterized by trunk valleys that hosted large valley glaciers. The Isarco and Pusteria (Rienza River) valleys were two of the largest tributary systems. Their junction is now located at Bressanone. Field surveys and a large number of drillings in the area between Bressanone and Varna/Sciaves allowed the stratigraphic architecture of the valley to be known during the late Pleistocene. Four distinct ice advances can be recognized. The thickest deposits are related to the LGM and are characterized by a fine-grained subglacial traction till up to 30 m thick. Two Lateglacial stadial moraines can be ascribed to the Isarco glacier, showing that the Modern Rienza lower valley was carved out as ice downwasted at the close of the LGM. A pre-LGM fluvial-lacustrine system filled the area, with contribution from both the valleys, indicating that the junction was located northwards with respect to today. Below, an older glacial unit made of a coarse subglacial traction till characterizes the succession, indicating that the fluvio-lacustrine phase represented an ice-free phase between two large advances. At the base, the cores drilled in the Isarco valley show a fluvial deposit pertaining to the Pusteria valley catchment, suggesting the presence of a narrow lower reach of the Rienza River. This suggested a persistence of the river valley at the valley junction in the Varna area a long before onset of the LGM. The presence of two large landslides testifies that the valley experienced also important slope dynamics; these were buried by LGM glacial deposits, while post-LGM slope accumulations are mostly related to minor events.

Assessment of the geochemical processes of groundwaters from the Continental Intercalaire (CI) aquifer in Dahar piedmont (Southern Tunisia)

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The association of environmental tracers with hydrogeochemical methods for the study of the CI in Southern Tunisia has determined the groundwater origin, the diffusive processes and the geochemical evolution of groundwaters from the Dahar uplands.
The isotopic analysis using heavy isotopes have shown depleted contents registered in groundwaters from the upper aquifer which is explained by the long residence time of water in the aquifer and its paleorecharge under a wetter climate. However, the enriched signals were registered in shallow boreholes indicating the contribution of the infiltrated rain water in the local recharge from Dahar outcrops. This spatial variability in stable isotopes signatures is related to the spatial distribution of precipitation, which is associated to longitude and seasonality. This reflects the irregular rainfall and climate changes. Also, this variability is governed by the proximity of the Mediterranean Sea and is materialized by the increase in precipitation from the continent towards the coast.
This evolution is consistent with the analysis of radiocarbon contents of the investigated system. The spatial distribution of radiocarbon revealed significant activities for some shallow wells from the lower aquifer, more particularly located near the Tataouine wadi. This confirms the dominant role of this wadi in the recharge of the aquifer. The paleoclimatic effect is confirmed by the ages calculated from carbon isotopes (14C/13C) and which vary from less than 2ka to more than 27ka.
The combination of these isotopic tracers indicates an evolution of groundwaters which might be interpreted as mixing processes between old and recent waters from the CI. The study of climate variability has shown that the recharge process is related to heavy rainfall involving surface flows through the wadis which represent the main recharge process spatially limited in this arid to semi-arid context.

2400 years of climate-human interaction over the Iranian Plateau: A multi-proxy record from Almalou Crater Lake, NW Iran

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Despite the significance of the Iranian Plateau in the development of human civilization little is known about climate variability and its impact on human societies in this region due to the paucity of paleoclimate data. Almalou Crater Lake sustains the growth of plants inside the crater of a dormant volcanic cone which is exclusively fed by rainfall during the spring and fall and snowfall during the winter. The ombrotrophic nature of Almalou Lake and preservation of the organic matter within the crater can potentially record changes in atmospheric deposition and paleo-environmental conditions over this region. Here, we present a high-resolution (sub-decadal) multi-proxy record of climate variability during the last 2400 years from a 3-m peat core recovered from the crater peat bog. Radiocarbon dates of eight samples along the core show a nearly constant rate of accumulation (average of 0.14 mm yr^{-1}, R^2=0.98) since 2404±25 cal yr BP. Downcore variations of selected conservative lithogenic elements as well as redox-sensitive elements reveal three short episodes (~ 150-y) at 450-600, 1150-1300, and 1400-1550 cal yr BP, and one prolonged period (500 y) of dust accumulation from 1600 to 2070 cal yr BP. which are coincide with historical records of drought and famine in Iran since 2000 yr BP. Total organic carbon (TOC) and the stable isotope composition of organic carbon ($\delta^{13}C_{TOC}$) values are positively correlated with the variation in lithogenic elements, while the significant drop in $\delta^{13}C_{TOC}$ values centered at ~80 yr BP reflects post-industrial anthropogenic input of carbon to the environment. Pollen data for anthropogenic herbs indicates several periods of expanded cultivation activities in the region from 2300-1950 B.P., 1600-1500 B.P. (middle part of the Sasanian Empire), 1000-900 B.P., 650-550 B.P., and 350-150 B.P. corresponding with the periods of low dust (wet periods). Wavelet analysis conducted on the first 1500 years and on the entire record (2400 year) for Si and Al show a significant periodicity centered at 261 y and 488 y corresponding to De Vries (~210 y) and 520-year solar cycle through internal climate feedbacks.

Magnetic susceptibility and elemental geochemistry from Shira Lake sediments reveal climate and environmental changes over the past 900 years in central Altai, Russia

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A 30-cm gravity core (GC4) from Shira Lake in central Altai region of Russia has been dated with 210Pb, 137Cs and AMS 14C methods. The detailed dating results not only show that the depositional history of the core was from AD 1115 to AD 2020, but also provide the sedimentation rates of 0.041 cm/yr, 0.006 cm/yr and 0.206 cm/yr during AD 1115~1460, 1460~1950 and 1950~2020, respectively. The core was subsampled at 1-cm interval. Magnetic susceptibility (MS) was measured for all samples on MFK-1A (AGICO) and calibrated to mass. Weight loss of acid-leach (0.5N HCl) (ALWL%) was conducted and its solution have been measured by ICP-OES for multiple elements on all samples. Loss of ignition at 1100°C (LOI%) and XRF analyses have performed on every second samples. TOC% and TON% were measured by EA. Based on the results, the sedimentation in Shira Lake over the past 900 years can be classified into four stages. Stage A: AD 1115~1255, strong surface runoff under wet climatic conditions brought more terrestrial input with low TOC and TON but relatively high magnetic minerals and acid-leachable elements. The lake was in oxide, fresh and oligotrophic conditions. Stage B: AD 1255~1460, the lake came deep with more lake productivity to produce organic matters. The acid-leach weight loss reached highest and MS became the lowest. Strongly increased Na_2O% during this period probably reflected strongly increased alpine glacier activity since Na_2O came from rock flour produced by glaciers. Stage C: AD 1460~1950, cold and dry conditions during the Little Ice Age resulted very low sedimentation rate. The lake was covered by ice most of the time, and productivity of the lake was very low. However, the organic decomposition was also low so that TOC content in the sediments kept unchanged. Stage D: AD 1950~2020, strongly warming condition and human impact allows strong increase in organic matter and salinity (Cl%) in the lake. The lake becomes more nutrification shown by strongly increased TOC, TON but decreased MS and reduction indicated by strongly decreased AL Fe and AL U concentrations.

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High-Altitude Tropical Cooling During the Last Glacial Maximum: Equilibrium Line Altitude Records from New Guinea

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As a net exporter of moisture and heat, the tropics play a major role in the global climate system. Exactly what role the tropics played in past climate changes, including in glacial-interglacial cycles, remains unclear, in a large part due to the lack of tropical terrestrial temperature records. Reconstructions of tropical sea surface temperatures (SST) and air surface temperatures at low altitudes have been debated but generally show a modest cooling (2-4°C) during the Last Glacial Maximum (LGM; ~26,000-19,000 years before the present). In contrast, proxies for tropical terrestrial temperatures suggest LGM temperatures ~5-6°C below modern, representing a long-standing discrepancy between the estimations of LGM temperature departures from marine and terrestrial records.

Here we focus on New Guinea, located in the heart of the Indo-Pacific warm pool, a massive zone of warm surface ocean water with a global climate influence. We investigate the magnitude and spatial pattern of LGM ELAs on New Guinea using newly available 1- arcsecond Shuttle Radar Topography Mission digital elevation models and the GIS tool GlaRe. With these tools, we reconstruct former glacier surfaces and calculate ELAs across the Highlands Region of Papua New Guinea and in the Mt. Jaya region in western New Guinea. We use prior work to estimate the ages of past glacier extents and modern ELAs. Our results show that glaciers on the island of New Guinea have LGM ELAs of ~3,400-3,700 m asl, corresponding to roughly 1,000 m of ELA change from the modern. Our results document a narrower range of LGM ELAs than previously reported across New Guinea, suggesting a relatively uniform temperature depression during the LGM.

Paleoclimatic and paleoenvironmental changes in the Pantanal region during the Holocene based on speleothem records

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The Pantanal is a large region located in the central parts of South America (140,000 km2) with a unique climate and vegetation setting. This region is subjected to seasonal floods which makes the Pantanal the biggest wetland on the planet, home of high biodiversity. In this region occur transitions between different biomes, such as the Amazon Forest, Cerrado (Brazilian Savanna), and Atlantic Forest, located to the North, East, and South of this region, respectively. The area also serves as a moisture pathway for the South American Summer Monsoon (SASM), which connects the Amazon Basin with the La Plata Basin. The two major drainage basins of South America. Due to the complex hydrology of the rivers and lakes of this region, it is necessary to combine multiple proxy archives from different parts of the Pantanal basin to understand its climate and vegetation evolution during the Holocene.

Here we present isotope records from stalagmites collected at sites located at the northern and southern borders of the Pantanal. Hiatuses in speleothem deposition during the mid-Holocene identified in several stalagmites indicate overall dry conditions in the region at this period. However, the drier conditions recorded at the northern portion of the basin precede similar conditions in the South by approximately two thousand years. Furthermore, summer insolation seems to drive the intensity of the SASM at the North Pantanal while its influence is weaker in the southern part. This establishes a gradient of moisture between a wetter North and drier South during the late Holcene. Our record also shows a strong multidecadal to centennial variability, which was probably responsible for the high hydrology complexity of the rivers of the Pantanal, which are subject to seasonal floods and migration of its channels and tributaries.

Coupled terrestrial and oceanic variability during marine isotope stage 19 reconstructed from biomarkers in the Chiba Composition Section

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Chiba Composition Section, an on-land marine sedimentary succession in central Japan covering Marine Isotope Stage 19, is of paleoenvironmental importance because of its high sedimentation rate and climatological/oceanographical settings. We detected long-chain alkenones (LCAs) and normal alkanes (*n*-alkanes) in this section. Variations in the unsaturation ratio of LCAs and the average chain length of *n*-alkanes showed the glacial–interglacial cycles with the millennial-scale oscillations, which are interpreted in terms of past summer sea surface temperature and annual air temperature changes, respectively. Variations in carbon isotope ratios (δ13C) of *n*-alkane showed different patterns for each carbon length. It seems to be caused by the difference in *n*-alkane soursecs. The relatively long-chain (C33–35) *n*-alkanes and relatively short-chain (C25–27) *n*-alkanes are highly deriveded from woody plants and herbs, respectively. δ13C variations in the long-chain and short-chain components mainly reflect changes in temperature and C3/C4 plant ratio, respectively. Using the multiple biomarker analysis, we revealed the seasonal variations of water structures in the Kuroshio Extension Front, as well as those interactions with terrestrial climate changes.

Poster - sessions 18, 27, 32, 133, 140, 170, 193

Spatial Dansgaard-Oeschger signals in Greenland ice cores and 40 years of analytical progress

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The 25 Dansgaard-Oeschger events, first named in the Greenland ice core dO18 signal from GRIP, are found in all deep Greenland ice cores with the significant corresponding signal also reflected in chemistry and impurities contained in the ice.Continuous flow analysis (CFA) is the preferred method nowadays to investigate the long Greenland ice cores for their impurity content and often includes NH_4^+, Ca^{2+}, and Na^+ ions, which besides being influenced by transport, provide information about forest fires, wind-blown dust, and sea ice, respectively. Here we present two datasets by CFA done at University of Copenhagen that covers Dansgaard-Oescheger events.

1. The Dye-3 ice core which was drilled to bedrock at the Southern part of the central Greenland ice sheet (65°11'N, 43°50'W) in 1979-1981. The southern location is characterized by high accumulation rates compared to more central locations of the ice sheet. Since its drilling, numerous analyses of the core have been performed, and the ice has been in freezer storage both in the USA and in Denmark. In October and November 2019, the remaining ice, two mostly complete sections covering the depths of 1753–1820m and 1865–1918m and represents both Holocene, Younger Dryas and Glacial sections (GS 5 to 12).
2. The RECAP ice core was drilled at the Renland ice cap all the way to bedrock in 2015 from an altitude above 2000 m and extends 584.11m. The glacial section is strongly thinned and covers just 20 meters of the ReCAP core, but nonetheless due to the high resolution of the CFA measurements all 25 expected DO events could be identified from the CFA analysis done in 2015 and 2016.

We compare the new high-resolution CFA record of Dye3 and the low resolution ReCAP with previous analysis done in the mid 80's and early 90's from the sites and thus evaluate the analytical progress made over the past 40 years. Further we compare overlapping time periods with other central Greenland ice cores and discuss spatial patterns of DO events in chemistry and impurities.

The regional expression of Late Pleistocene climate and environmental variability in the alluvial record of Côa River Valley (northeast Portugal)

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In a fluvial setting, compositional and textural data of alluvial sedimentary deposits can provide crucial information on the paleoenvironments of the corresponding catchment when the geology and geomorphology of the source area, the mechanical selection processes during transportation, and possible recycling effects are considered in their interpretation. In this type of sediments, the clay minerals are commonly produced by weathering processes and, generally, the degree of chemical weathering is strongly controlled by climate. In the framework of the ongoing CLIMATE@COA project (COA/CAC/0031/2019) and giving continuity to a previous one (PALÆOCÔA - PTDC/EPH-ARQ/0326/2014), a ~3.5-m-thick floodplain sequence exposed at the Cardina/Salto do Boi archaeological site, in the Côa River Valley (northeast Portugal), was analysed. Some vertical variations in the sedimentary facies, bulk chemical composition (major and trace elements, including REE), degree of chemical weathering (by geochemical indices), grains size, and clay mineral assemblage, as well as in the petrographic characteristics and abundance of organic particles, were observed. Twelve luminescence ages, obtained on feldspars using a multi-grain pIRIR protocol, led to the establishment of a robust age-depth model for this alluvial body covering the time interval ~150-23 ka. The observed stratigraphic changes reveal the relationship between sedimentary environments and the degree of chemical weathering during the penultimate glacial-interglacial transition, the last interglacial and most of the last glacial cycle. Preliminary results suggest that late Marine Isotope Stage (MIS) 6 (~150-132 ka) and MIS 5e (~132-116 ka) were characterized by overbank sedimentation under low-intense precipitation with periods of enhanced effective moisture (rainfall seasonality). The MIS 5d-5a interval (~116-71 ka) seems to be dominated by low-water vertical sedimentary accretion linked to progressively colder but still humid conditions. During MIS 4, 3 and 2 (~71-23 ka), the alluvial sedimentation, punctuated by incipient pedogenic activity, witness the climatic variability documented for this period in the North Atlantic marine record. A sedimentary hiatus, without a clear erosion, is highlighted at around 40-32 ka. This multi-analytical approach, combining geomorphological, sedimentological, geochemical, petrographic, and geochronological analyses, brings new insights into the Late Pleistocene environmental changes and frames it within the regional evolutionary pattern of the western Iberia climatic variability.

Transition times of a particle driven by Lévy noise in a double well potential

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Inspired by the previous evidence that the DO events can be modelled as transitions driven by Lévy noise, we perform a detailed numerical study of the average transition rate in a symmetric double well potential for a Langevin equation driven by Lévy noise. The potential considered has the height and width of the potential barrier as free parameters, which allows to study their influence separately. The results show that there are two different behaviours depending on the noise intensity. For high noise intensity the transitions are dominated by gaussian diffusion and follow Kramer's law. When noise intensity decreases the average transition time changes to the expected power law only dependent on the width on the potential and not on the height. Moreover, the symmetries of the equation allow to find a scaling under which the transition time collapses for all heights and widths into a universal curve, only dependent on α.

The role of saddles for transition paths in a multiscale dynamical landscape

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Climate proxy records feature a variety of abrupt transitions between competing climatic states on a hierarchy of scales. An intuitive framework to understand the metastable Earth system may be offered by the notion of a non-equilibrium dynamical landscape. In stochastic dynamical systems, the quasipotential introduced by large deviation theory generalises the concept of an energy potential to systems out of equilibrium. Transition paths are expected to cross at “mountain passes” between coexisting basins of attraction where the quasipotential takes local minima along the basin boundary, i.e. saddles, or Melancholia states. However, noise-induced transition paths do not always cross near a saddle. Here, we demonstrate this using simple conceptual models of bistable dynamical systems, such as box models of the Atlantic Meridional Overturning Circulation (AMOC). We discuss the conditions under which transition paths avoid Melancholia states, relating these cases to the boundary quasipotential curvature. This highlights the differing viewpoints of critical transitions taken in large deviation theory and fast-slow systems, which here we aim to reconcile. Furthermore, we debate to what extent the quasipotential generates a geometrically interpretable global landscape. Clarifying the role of Melancholia states for critical transitions marks an important step towards a better understanding of tipping mechanisms and probabilities.

Marine Isotope Stage 5: a better time interval to understand Dansgaard-Oeschger events during the last glacial cycle?

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The last glacial cycle is marked by abrupt, millennial-scale climate changes known as Dansgaard-Oeschger events (DOs) that links to changes in the strength of Atlantic Meridional Overturning Circulation (AMOC). Paleoclimate proxies consistently show that DOs were much more active during Marine Isotope Stage (MIS) 3 (a time interval by far paid major attention for DO dynamics) than MIS 5 (a warmer period with less DOs). With aid of available proxies and climate modeling results, I propose that occurrences of DOs during MIS 5 might be mainly related to AMOC changes forced by changes in climate backgrounds (e.g. global ice volume and atmospheric CO2 level), while those during MIS3 are additionally associated with noise-induced and/or unforced spontaneous AMOC changes. This indicates that MIS3 characterizes a more complex nature of DO dynamics than MIS5 which might be a better time interval to understand deterministic mechanisms accounting for occurrences of DOs.

Late Pleistocene fluctuations of precipitation in the south-eastern Mongolia

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Many paleolake depressions are distributed aces in the south-eastern Mongolia. The study area, Bayan-tohom Govi, is located at the Ongon Soum, the south-eastern Mongolia. This area is sensitive to the climatic change because it is located at the summer monsoon limit without glacier melting water. The present study elucidated the fluctuation of precipitation in Late Pleistocene through analysis of palaeo-lacustrine deposits obtained from desiccated saline lake. The results of analysis show that the contents of biogenic silica and organic matter fluctuated greatly with short period. This fluctuation occurred before 28 ka (OSL dating). Increase of organic matter and biogenic silica mean that of vegetation around the paleolake and that of precipitation. These results mean that fluctuation of precipitation with short period associating with D-O cycle. D-O cycle possibly affected the fluctuation of precipitation in the south-eastern Mongolia.

The last Neanderthals and first modern humans in Swabian Jura of southwestern Germany

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The caves of the Swabian Jura, particularly the site in the Ach- and Lone Valleys, provide one of the best records available for studying the lifeways of the late Neanderthals and the first modern humans in the Upper Danube region. Although changing environmental conditions and a gradual cooling characterized MIS 3 in the region, in many respects the environmental conditions of the late Middle Paleolithic, the period of the last Neanderthals, and the early Upper Paleolithic, when modern humans arrived in the region, were broadly similar. Thus the fluctuations in the region's flora and fauna and cannot explain the dramatic shift in material culture during this time. Drawing mainly on recent excavations at sites including Hohle Fels, Geißenklösterle and Vogelherd, this paper considers the changing lithic and organic technology of the late Middle Paleolithic and the early Upper Paleolithic. The talk also presents evidence for shifts in symbolic aspects of the material culture of this period between roughly 50,000 and 35,000 years ago. The archaeological record documents an occupational hiatus between the last Neanderthals and the first modern humans of the region's Aurignacian, as well as a clear change in the nature of human interaction and symbolic communication. This change in technology and the symbolic repertoire of the modern humans was accompanied by increasing population densities and a demographic expansion that continued to fostered social-cultural innovations that accelerated the geographic expansion of modern humans across Eurasia and beyond.

Can climate models simulate Dansgaard-Oeschger type events?

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Dansgaard-Oeschger (D-O) events, millennial-scale climate oscillations between stadial and interstadial conditions (of up to 10-15°C in amplitude at high northern latitudes), occurred throughout the Marine Isotope Stage 3 (MIS3; 27.8 – 59.4 ka) period. By examining the behaviour of a range of climate models, we show that no model exhibits D-O like behaviour under pre-industrial conditions. Not all, but likely the majority of models, exhibit D-O like oscillations under MIS3 and/or full glacial conditions, when run for long enough under the optimal MIS3 configuration. Greenhouse gases, orbital, and ice-sheet configurations are crucial to model behaviour: intermediate ice-sheet configuration; medium-to-low MIS3 greenhouse gas values; and low obliquity are conducive to D-O type behaviour in models. These findings have allowed us to design a standardised protocol for a long MIS3 simulation with an optimal configuration to promote D-O events and which could be used for in-depth investigations of simulated D-O behaviour, alongside model tuning for tipping points.

Pre-Columbian land use and environmental impact in the Monumental Mound Region of Amazonian Bolivia

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The rainforest-savanna mosaic landscapes of northern Bolivia (the Llanos de Moxos) display some of the strongest evidence for pre-Columbian (pre-1492 AD) landscape domestication across Amazonia. Between 400 and 1400 AD, people undertook earthwork engineering of these seasonally-flooded landscapes on a massive scale to produce the most complex pre-Columbian society yet discovered in Amazonia – the Monumental Mound Culture (MMC). This 'earth-moving' society built over 150 monumental habitation mounds, interconnected with each other and neighbouring lakes via a complex network of causeways, canals and artificial ponds. Emerging archaeological and palaeoecological evidence suggests that the MMC may have practiced intensive, large-scale maize agriculture in a region which, until very recently, was considered suitable only for cattle ranching. This discovery raises the fundamental question of how this complex society managed its natural resources. Did the MMC have a centralised maize-based economy which extended across the MM region (MMR), irrespective of local differences in natural resources? Or did diet and land use vary geographically across the MMR according to variations in natural resource availability; e.g. forest cover, rivers, flood/drought risk, soil quality?

Here, we attempt to address these questions by examining the environmental history of Laguna Loma Suarez, a small oxbow lake next to a habitation mound (Loma Suarez) in the western part of the MMR This is an ideal site because it has markedly different natural resources from those of previously studied sites in the centre of the MMR, in being situated in gallery forests of a major river (Rio Mamoré) which experience much greater seasonal flooding.

A high-resolution, multi-proxy approach was taken to reconstruct the environmental history of Laguna Loma Suarez – involving pollen and charcoal analyses, as well as x-ray fluorescence spectroscopy. The record is chronologically constrained using a Bayesian age-depth model, built from multiple radiocarbon dates. By comparing these data to other records obtained from the centre of the Monumental Mound Region, we will determine the extent to which different forms of land use (burning, deforestation, crop cultivation) varied across the MMR over the past two millennia.

From sea to summit: synchronous and asynchronous Holocene vegetation shifts across a transect in Northern Greece

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Holocene vegetation history has been driven by climate change, disturbances and land use. Especially the introduction of agriculture led to significant changes in the natural biomes and environments of Europe. The European neolithisation started in Northern Greece more than 8000 years ago, with the arrival of new crops and livestock. The interactions between human activities, climate and vegetation are complex, as they influence one another. Disentangling the contributions of climate and land use to vegetation change requires the investigation of different sites across vegetation and climatic gradients, and through time.

Here, we present Holocene vegetation changes along a transect from the Aegean coast to the Pindus mountains. The transect spans different vegetation types, from evergreen broadleaved woodlands to the tree line ecotone, and across altitudinal belts, from sea level up to 2000 m asl. We show the vegetation and fire histories from Limnes Volvi, Vegoritida, Zazari, Orestiás Kastorias and Drakolimni Smolikas, all located in Northern Greece.

The vegetation histories from the submediterranean lowland sites show the establishment of mixed deciduous oak forests at the start of the Holocene. During the Early Holocene we can detect synchronous phases of closed and open forest conditions, suggesting a predominance of regional drivers. Around 8,500 cal BP, the data show a significant decline in forests, together with an increase of steppe vegetation and the regular appearance of anthropogenic indicators. This combination may indicate that both climate and land use played a role. The vegetation histories from the coastal mesomediterranean and the subalpine site are still preliminary but are essential to contextualise the other results. Specifically, they provide insights into the linkages between climate, vegetation, fire and agriculture at coastal (mesomediterranean), intermediate (inland submediterranean) and marginal (subalpine) sites. The ability for agriculture to establish depends on several factors such as proximity to the Mediterranean Sea, duration of the growing season, moisture availability, frost occurrence, terrain accessibility and soil development. We hypothesise that specialised land use approaches such as summer farming or transhumance in very remote areas may have followed centuries or millennia after the introduction of agriculture at coastal and intermediate sites.

A threshold in the collapse and recovery of Atlantic Meridional Overturning Circulation in response to different interglacial conditions

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Previous studies suggest that the Atlantic meridional overturning circulation (AMOC) is weakening in response to the global warming. Two equilibrium states are considered to exist in AMOC, which may rapidly push the current typical ('on') state to a collapsed ('off') state when the freshwater injection in the regions of deep-water formation across the threshold. Some simulation studies suggest that the threshold may be influenced by several factors, such as the region and the change rate of freshwater hosing. Paleoclimate records indicate that the change of AMOC occurred also during past interglacials. However, it is not fully clear to what extent the stability of the threshold could be affected by different interglacial boundary conditions. In this work, we conducted a set of sensitivity experiments with the Marine Isotope Stage 13 (the coolest interglacial over the last one million years) and the present interglacial boundary conditions employing two Earth system models, the Community Earth System Model and the LOVECLIM, to explore the AMOC and global climate response to freshwater hosing. Both models show a marked response of AMOC to a freshwater flux threshold of about 0.047 Sv in the Greenland-Iceland-Norwegian (GIN) seas. AMOC gets weakened (recovers) drastically when freshwater flux rises beyond (falls below) the threshold under the 'on' ('off') state. This threshold value is hardly affected by changes of orbital parameters or greenhouse gases between the two interglacials but is sensitive to hosing region and change rate of the freshwater. The threshold value of the freshwater flux found in our study is similar to the threshold suggested by proxy reconstructions below which rapid AMOC recovery and warming occurred at the end of the Oldest Dryas and the Younger Dryas. Further analysis reveals possible and apparent transitions of the magnitude and spatial pattern of the global climate response to freshwater hosing before and after the threshold during the MIS-13 interglacial. Our results imply that the relationship among AMOC, freshwater hosing and associated climate change during past interglacials could be a reference for future AMOC deceleration.

Decadal-scale ostracode assemblage records from two box cores detail changes in Beaufort Sea coastal areas during the last few centuries

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We examined ostracode assemblages from two high-resolution (decadal-scale) box cores collected in the Beaufort Sea during the 2022 Arctic Challenge for Sustainability (ArCSII) expedition, a project of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). Ostracoda (bivalved Crustacea) comprise a significant part of the benthic meiofauna in the Pacific-Arctic region, including more than 50 species, many with specific ecological tolerances. As a result, these meiofauna taxa hold potential as useful indicators of past and present ecosystem changes. Two relatively shallow coring sites, located near Barrow Canyon (BC2, 224m, 71.90, -154.15) and in the Mackenzie Trough (MT1, 57m, 69.97, -137.24) on the Beaufort Sea slope/shelf, are ideally located to record variations of the Bering Strait throughflow and Mackenzie River outflows during the past ~150-200 years. Investigation of the box cores, 26-30cm in length, will focus on the impacts of recent anthropogenic forcing on the coastal ecosystem in the Alaskan and Canadian Beaufort Sea. Assemblages from the cores' upper-most sediments will be compared to those documented from a nearby multicore collected in 2013 (HLY1302, MC29; Gemery et al., in press). Preliminary results show that ostracode abundance and distribution are related to bottom water temperature, salinity, organic carbon deposition, and sediment substrate, which are primarily tied to the transit of summer Pacific water masses. Radiocarbon dating of the cores and statistical analyses of the faunal data are underway that will enable inferences about the regional paleoceanography of these two areas. Overall, this study will offer unprecedented micropaleontological records that will provide insight into the impacts of recent temperature, salinity, sea-ice, and erosional change on the coastal Beaufort Sea ecosystem.

Late Holocene environmental changes on the Zackenberg Delta, NE Greenland

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Arctic ecological research has sparked increasing interest among scientists because of the high vulnerability of this region towards ongoing anthropogenic climate warming. Even if Greenland's paleoclimatic records based on ice-cores are well known, paleoecological studies tracking the biotic response towards climatic oscillations are scarce. In this context, pollen analysis of Holocene sedimentary lacustrine records becomes a useful proxy to understand climate change in last thousands of years and to track its effect on the High Arctic vegetation of Northeastern Greenland.

The Lomsø sedimentary core was obtained from a lake located in the lowland delta formed at the end of the Zackenberg Valley, in coastal NE Greenland (74°N). The core was analyzed by a multi-proxy approach ranging from geochemical to biological studies. The age-depth model indicates this core records the last 4700 cal yrs BP with two very differentiated units showing the evolution from a fluvial/deltaic depositional environment to a thermokarst lake originated thanks to permafrost processes around 2400 cal yrs BP.

Pollen assemblage data shows that despite its vulnerability to climate change, the vegetation near lake Lomsø has remained stable, as shown by the lack of abrupt changes. The palynological record starts about a century after the onset of lacustrine sedimentation and displays four pollen zones: LOM-I (2300 – 1450 cal yrs BP), LOM-IIa (1450 – 700 cal yrs BP), LOM-IIb (700 – 70 cal yrs BP), and LOM-III (last century). Even with over-represented fen taxa Luzula/Juncus, which reigns on every single zone, the main vegetation types dominated by Poaceae, Cyperaceae, Juncaceae, Salix or Cassiope are well represented. This vegetation mosaic shows the persistence of high soil moisture conditions with overall cold climate and extensive snow-beds throughout the record, showing a weak warming short period that peaked around 1100 cal yrs BP followed by a Little Ice Age-related cooling trend. This trend is reversed towards the present owing to the anthropogenic-related global warming as shown by the expansion of dwarf shrubs on the latest samples.

Our results shows the strong resilience of lowland Zackenberg tundra vegetation despite Late-Holocene macro-climate changes, and its vulnerability towards recent climate change.

Boreal (Eemian) transgression in the northeastern White Sea Region: stratigraphy and high-resolution record of past environmental changes

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In relation to the overall importance of reconstructing interglacial marine environments and water mass evolution in subpolar and polar northern regions we carried out a high-resolution investigation of a 455 cm thick sediment sequence of the Boreal (Eemian) marine beds directly overlying Moscovian (Saalian) till in Bychye-2 section on the Pyoza River. Evaluation of past events is carried out through analysis of changes in lithology, microfossils (foraminifers, ostracods, pollen, aquatic palynomorphs) and benthic foraminiferal isotopes ($\delta^{18}O$, $\delta^{13}C$). Stratigraphical subdivision is based on the succession of palynological zones that are correlated with the previously established regional zones. The latter are age constrained on the basis of correlation with dated western European palynological zones. Marine sediments of Bychye-2 section accumulated from the end of Moscovian glacial (>131 ka BP) until *ca.* 119.5 ka BP. Three successive phases in the evolution of the transgression have been identified: 1) a seasonally sea-ice covered relatively deep freshened basin of the initial phases of flooding (360-455 cm, >131-130.5 ka BP), 2) a deep basin of the maximum phase of flooding with less extensive sea-ice cover (290 -360 cm, 130.5-130.25 ka BP), and 3) a shallow basin with reduced seasonal ice cover (0-290 cm, 130.25-119.5 ka BP). The flooding of the territory by cold Arctic waters was rapid, as evidenced by both: the lithological contact between the till and marine clays and the composition of microfossil assemblages represented by river-proximal Arctic species together with the species preferring water depths of 40–50 m. The regression in the region started early, about 130 ka BP, which indicates that the glacioisostatic rebound of the territory was ahead of the global eustatic sea level rise. The most warm-water and taxonomically diverse assemblages of foraminifers and ostracods, containing species typical of the Baltic Sea, were recorded during the regressive stage, especially in the time interval from about 128 to 124 ka BP. This probably gives evidence for a long-lasting connection of the White and Baltic Seas for 6-7 thousand years in total starting from the onset of the transgression.

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Stalagmite-inferred prolonged droughts in northern Africa during Heinrich events

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Paleo-proxy records covering the last glacial period have highlighted the global climate impact of Heinrich events. However, few terrestrial paleoclimate records with absolute chronologies in northern Africa are available, hampering the understanding of past abrupt climate change in this region. Here, we present dating results with U-Th techniques from a broken stalagmite collected from La Mine Cave, Tunisia. Results show that this stalagmite deposited from 190 to 40 thousand years ago (ka). The abrupt droughts of the last three hiatuses at 78.6±1.9-59.3±0.6, 58.7±0.8-54.0±0.4, and 51.9±0.6-44.5±0.3 ka correspond to intervals with low values of sea surface temperature in the eastern north Atlantic and the Mediterranean and matches the occurrence of Heinrich events 6, 5a, and 5. In comparison with previous marine records and with a transient numerical simulation, the multi-centennial-to-millennial droughts could be caused by weak Atlantic meridional overturning circulation (AMOC), which altered the westerlies away from northern Africa. Our results suggest that the regional hydroclimate was dominated by orbital forcing with modification of the internal forcing such as atmospheric and oceanic circulation.

Early Pleistocene dysoxia in circalittoral to shallow bathyal marine deposits of the island of Rhodes (Greece)

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The eastern Mediterranean Sea is known for its sapropel deposition during the Pliocene and Quaternary. Sapropel formation is commonly attributed to an intensification of the African monsoon at times of northern hemisphere summer insolation maxima and related increase of riverine fresh-water and nutrient input, resulting in a temporary stagnation of deep-water masses.

On the island of Rhodes, marine fossiliferous sediments of late Pliocene to middle Pleistocene age are exposed in distinct locations along the eastern coast. The sediments of each location represent an individual depocenter, reflecting the paleoenvironmental and neotectonic history of the island.

Here we present a new benthic foraminiferal record from the Plimiri 5 sediment section, located at the south-eastern coast of Rhodes, which provides insights in the paleoenvironmental conditions during the early Pleistocene. Changes in the diversity and composition of the benthic foraminiferal fauna indicate periodic occurrences of dysoxic conditions at the sea floor, comparable to the sapropels of the deep Eastern Mediterranean basins. The recurring pattern of high abundances of eutrophic indicator species, of up to 99 percent, suggests transient phases of oxygen deficiency at shelf and upper slope environments, i.e. between water depths of approximately 100 and 270 m. The species identified within these layers (genera *Brizalina*, *Rectuvigerina*, *Stainforthia*) are associated with periods of dysoxic conditions. The dysoxia can be attributed to increased fresh-water and nutrient input from the island resulting in enhanced primary productivity of near-coastal waters and associated organic matter fluxes to the sea floor. Our data also suggest that the deposition of the Plimiri sediments took place in a basin, which experienced times of restricted exchange of waters with the open ocean due to orbital-driven and/or tectonical-driven sea-level changes.

Deglacial radiocarbon ventilation age changes in the central and eastern Mediterranean Sea

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Understanding the mechanisms underlying past circulation changes in the Mediterranean Sea during rapid climatic events and their impacts on the implementation of deposits rich in organic matter (ie ORL, sapropels) is a major challenge in the field of paleoceanography. We use water-column radiocarbon reconstructions to assess the structure and age of the intermediate and deep-water masses in the central and eastern Mediterranean Sea since the last deglaciation. Today, the vertical mixing and thus the mixing time of the water masses occurs very quickly at the scale of the Mediterranean basin resulting in a minimal surface-to-deep gradient in ^{14}C with a ventilation age of ~100 years. Here, we reconstruct past ventilation age changes of intermediate and deeper water masses by measuring the ^{14}C age difference of pairs of planktonic and benthic foraminifera taken from marine cores bathed by intermediate and deep water masses collected in the Sicily Strait and Levantine basin respectively. Our results show extremely ^{14}C depleted water masses between 11 kyr to 9 kyr associated to a reduction in Mediterranean convection and inducing significant water column stratification between □700–1200 m water depth. This phase was followed by a break-up of the stratification at 700 m in the Levantine basin at 6.3 kyr, while re-ventilation at 1200 m occurred only since 4.5 kyr as indicated by the Sicily Strait record.

Arid conditions in southern Iberia during the early-middle Holocene transition recorded by stable isotopes of gypsum in Laguna de Medina (Cádiz)

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The southern Iberian Peninsula has been particularly vulnerable to climate changes during the Holocene. Such environmental variability was recorded by the sedimentary sequences of the numerous lakes of the Guadalquivir Basin. Here, we analyze the oxygen and hydrogen stable isotopes ($\delta^{18}O$ and $\delta^{2}H$) of structurally-bound hydration water of gypsum ($CaSO_4 \cdot 2H_2O$) from the sedimentary sequence of Laguna de Medina (Cádiz), in order to reconstruct the isotopic composition of the lake water in the past. Gypsum is particularly abundant in the sediments from 18 to 24 m deep, corresponding to ages from ~7.0 to ~9.0 cal. ky BP. The sediments of Laguna de Medina recorded an intense dry period around □7.7 cal. ky BP, as revealed by the presence of gypsum with elevated $\delta^{18}O$ and $\delta^{2}H$ values (up to 7.4% y 26.1%, respectively) of the paleo-lake water. This finding suggests that the original solution from which gypsum formed was highly evaporated. Such conditions may be attributed to an arid phase around 7.5 cal. ky BP, as described also in other western Mediterranean paleoclimate records. However, a connection with the cold/dry 8.2 ka event cannot be ruled out given the chronological uncertainties of the lake sedimentary record around this period. Research in progress aims to quantify climatic parameters (humidity and temperature) during this dry stage from the Laguna de Medina sediments and to improve the chronology resolution around this period.

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Human-environmental interaction, seismotectonic impacts and climate oscillations in the Central Mediterranean – Multi-methodological investigation of lake sediments from Corfu (Ionian Islands, Greece)

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The Mediterranean has been identified as particularly vulnerable to rapid climate changes (RCCs) during the Holocene. RCCs are assumed to be one of the main environmental factors causing distinct cultural and socio-economic changes. Within the Mediterranean, RCCs relate to the inflow of cold and dry continental polar air masses caused by intensification of the semi-permanent Siberian high-pressure zone leading to increased energy transfer between surface water and traversing winds. Although the number of high-resolution Holocene geoarchives in Greece has increased during the last decades, available proxies are often discontinuous or cover in detail only distinct Holcene time intervals leading to incomplete and partly diverging interpretations. In combination with chronological uncertainties, our understanding of the impact of RCCs on coastal and landscape evolution and their fingerprints within natural terrestrial archives requires further research.

We present a new sedimentary record from a palaeo lake in the Giannades polje on Corfu Island, Greece. Following geophysical prospection and in situ Direct Push electrical conductivity measurements, we retrieved a 16 m long sediment core partly containing finely laminated sediments composed of grey-clastic, dark-organic and yellowish-brown carbonaceous laminae. Our studies include high-resolution X-ray fluorescence (XRF) core scanning, grain size and magnetic susceptibility measurements, smear slide and microfaunal analysis as well as determination of total carbon and nitrogen contents. The age model is based on radiocarbon dates yielding consistent ages from ca. 7500 BC until 1700 AD, overall indicating an average sedimentation rate of 1.4 mm/a.

Observed changes in proxy data will be associated with environmental changes related to climate (RCCs) and human-impacts. In addition, we expect the Giannades polje geoarchive to comprise signals of local and regional seismo-tectonic events, as they have been evidenced by geoarchaeological investigations of regional coastal sites. Our studies are embedded in the joint research program SCaLES combining dendro- and sclerochronological and speleological studies on a larger spatial and temporal scale to increase the understanding of these environmental influences. This approach will allow detailed correlations with other regional to interregional archives of climate and environmental change.

Deglacial Mediterranean-basins link: old carbon-enriched eastern waters and collateral consequences for western aragonite mounds development

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A Mediterranean Thermohaline Circulation slowdown related to deglaciation and monsoon dynamics have largely been discussed, but it yet remains insufficiently constrained. With the aim of investigating changes in water mass residence time (as a key parameter to elucidate inter-basin communication variations) and its potential environmental impacts, we present a multi-proxy-archive study in the Western Mediterranean mid-depth based on cold water corals radiocarbon ventilation ages, along with foraminiferal O_2 and $[CO_3^{2-}]$ qualitative inferences. At ~300m, we find: 1) two aged-water pulses at Younger Dryas and ~8.2 event, respired carbon enriched and coincident with low CWC mound growth, and 2) a well-ventilated water pulse in between, parallel to a CWC mound flourishing stage. Our results allow changes in ventilation rates to be shown, quantified, and timed in association with periodical phases of MedTHC weakening, as well as suggesting enriched respired carbon episodes as a potential cause of decreased mound growth rates via aragonite dissolution.

Past 20,000 years of climate history in the Northern Ionian Sea as recorded by Calcareous Nannofossil assemblages

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Calcareous nannofossils are the fossil equivalent of unicellular marine algae whose ecology and vital functions are driven by environmental parameters within the photic zone (e.g. temperature, salinity, sunlight and nutrient supply). High-resolution quantitative analyses were performed on the sediment core ND14Mbis collected in the northeastern part of the Ionian Sea at 665 metres of water depth (Next-Data 2014 cruise). The core consists of 332 cm of greenish to greyish fine sediments in which is comprised the Sapropel layer S1 (105-126 cm) studied by Checa et al. (2020) and Cascella et al. (2021). The chronology of ND14Mbis core is based on 10 radiocarbon ^{14}C AMS measurements (Checa et al., 2020) and it indicates an extrapolated age of 20.66 kyrs BP at the bottom. Micropaleontological associations were statistically analysed with R-software and compared with sediment compositional proxies obtained through XRF-core scan.

Changes in abundance of the main surface oligotrophic species *Emiliania huxleyi* <4 μm and the deep dweller taxa *Florisphaera profunda* (N-Ratio) were used to reconstruct stratification/vertical mixing changes in the upper water column and the associated variations in paleo-productivity. Reworked specimens were analysed to acquire information on sediment transport and to reconstruct regional scale runoff and/or precipitation changes. The bulk elemental geochemical composition of Ba/Al ratio was used as a paleoproductivity proxy while the Si/Al ratio was used to detect inputs of aeolian dust. The cluster analysis, performed on calcareous nannofossil assemblages, highlights the principal climatic phases that occurred during the last 20,000 years (e.g. Heinrich Stadial 1, Bølling-Allerød, Younger Dryas, etc.). The boundary between Late Pleistocene-Holocene was confirmed by the drastic reduction of *E. huxleyi* >4 μm, *Gephyrocapsa muellerae* and small *Gephyrocapsa*.

Cross correlation analysis was performed on selected calcareous nannofossil groups (e.g. Upper and Lower Photic Zone, Placoliths, etc.), reworked specimens and geochemical proxies to highlight phase/antiphase periodicity occurred in the last 20 kyrs.

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The AMUSED Project: A MUltidisciplinary Study of past global climatE changes from continental and marine archives in the MeDiterranean region

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The INGV-funded AMUSED project (https://progetti.ingv.it/index.php/it/amused) aims to reconstruct the climatic variability in the central Mediterranean region during the Middle-Late Quaternary by integrating paleoclimate multi-proxy data acquired from different paleoenvironmental settings. Specifically, we investigate lacustrine and marine successions and speleothems to evaluate, within a narrow geographical range and at different temporal scales and resolution, the expressions of the climate variability in three different sub-systems. We focused on: i) two parallel 116 m and 126.5 m-long cores recently retrieved from the Castiglione maar (central Italy) after a geophysical exploration survey, ii) speleothems collected from selected caves of the central Apennine area, and iii) two already available marine cores (NDT09 and NDT12) recovered in the Tyrrhenian Sea during the NextData2016 cruise. High-resolution multi-proxy investigations (including palynological, micropaleontological, geochemical, stable isotope, paleomagnetic, tephrocronological analyses on both lacustrine and marine sedimentary records, and stable isotope on stalagmites) are in progress on the selected archives. A robust chronology was obtained by combining both direct and indirect $^{40}Ar/^{39}Ar$ dating of the tephra layers, paleomagnetic analyses and ^{14}C dating of the lacustrine and marine sediments and by U/Th chronology for speleothems. Another objective of the project is to estimate the natural soil CO_2 emission in selected areas the city of Rome and the Colli Albani district and to made actions of mitigation of the emission in a selected high gas releasing zone by planting ad hoc CO_2 adsorbing vegetation.

The 8.2 ka event in the Dead Sea: tracking a high-latitude disturbance in the Mediterranean

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The last deglaciation is an ideal time interval to investigate the effect of climatic and oceanic disturbances occurring at high latitude on the hydrological regimes of the Mediterranean Sea. In particular, a series of disruptions of the Atlantic Meridional Oceanic Circulation (AMOC) has punctuated the transition from glacial to interglacial conditions, with the so-called 8.2 ka event being the youngest one. After the publication of recent results showing the existence of instable climatic conditions in the Dead Sea during the Younger Dryas, we examine here the environmental record during the 8.2 ka event to illuminate the effects of the background climate (colder to warmer) on hydrological distrubances linked to AMOC disruptions. We performed a coupled limnological and geochemical analysis of sediments deposited in the deeper part of the Dead Sea (IDCP site 5017A), which showed the occurrence of repeated mass wasting deposits related to intense erosive activity in the watershed of the Dead Sea. Newly-acquired neodymium and strontium isotopes also show a rapid change in sediment provenance and a hiatus in outcrop sequences from western lake shores suggests a drop in lake level at that time. Ongoing classification of mass wasting events and the integration of other well-dated regional records and paleoclimatic simulations will provide additional insights on the erosional processes operating at that time, as well as the climatic regimes associated.

Rapid response of the Adriatic convection cell during the Sapropel S1: New insights from Nd isotopes

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The Sapropel events are intrinsically linked to changes in the Mediterranean thermohaline circulation (MedTHC). These organic-rich sedimentary layers that typically appear in the E-Mediterranean, have been often attributed to the combination of enhanced biological production in the surface ocean and to a deficit in the renewal rate of deep waters leading to severe anoxic conditions that helped preserving organic matter in the sediment. There is a general lack of knowledge on how the main intermediate and deep convection cells in the E-Med responded during sapropels. In this work we present a new reconstruction of the changes of the MedTHC circulation system during Sapropel 1 using Nd isotopes (εNd) in the Adriatic-North Ionian Sea region. The study site is located at the convergence and mixing between the outflow of Adriatic Deep Waters (ADW) and the arrival of E-Med Levantine Intermediate Water (LIW). New results using Nd isotope ratios illustrate changes in the mixing proportions of these two endmembers (ADW vs. LIW), and clearly show two distinctive collapse intervals during the sapropel (S1a and S1b) as a result of reduced strength in the ADW convection cell and increased presence of LIW. The two sapropel intervals where rapidly interrupted but a relatively short period where ADW resumed its convection and outflow into the north Ionian Sea. Further support to this interpretation comes from U/Mn ratios measured in foraminifera, gran size measurements as well as benthic foraminiferal fauna supporting the idea that the changes in the intensity of deep water convection preceded both the establishment of anoxic conditions at depth and the increased organic matter export to the sediments. By using an stochastic box model of the Mediterranean Sea enabled for isotopic tracers in seawater following a Monte-Carlo approach we demonstrate that the Nd isotpe resutls measured in the north Ionian Sea are consistent with a complete shutdown of the ADW outflow during the sapropel events. The collapse of ADW convection cell led the deposition of the last sapropel layer and favoured the dominance of LIW at intermediate depths in the E-Med water column.

Present and past variability of the Mediterranean Outflow Water using Nd isotopes

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The Mediterranean Outflow Water (MOW) is a source of heat and salt into the Atlantic Ocean, and it has been proposed that it preconditions the water masses that participate in the production of deep water into the north Atlantic, or the Atlantic Meridional Overturning Circulation (AMOC). Although some modelling and proxy studies have suggested that past changes in properties of the MOW could have consequences to the AMOC, this impact is still being debated. Seawater Nd isotopic composition (ε_{Nd}) has been used as a conservative water mass tracer in the modern ocean, but also as a paleo-circulation proxy measured in the Fe-Mn coatings of foraminifera. One of the advantages of using Nd isotopes is that this tracer can be used to calculate the mixing and export rates of water masses nowadays, but also in the sedimentary record, which could help estimate the mixing and exportation rates of the MOW into the North Atlantic in the present and in the past. But recently, some studies have shown processes that can modify the signal of ε_{Nd} in seawater and consequently, in the sedimentary archive (for example pore water reactions). In order to test the reliability of ε_{Nd} as a tracer for the MOW, we analyze ε_{Nd} from seawater samples, foraminifera Fe-Mn coatings and sediments from transects located in the Iberian Margin. Seawater results show that ε_{Nd} can be used to identify the different water masses located in the Iberian Margin. Considering that the ε_{Nd} values of the MOW differ from the values of the surrounding Atlantic waters, Nd isotopes seem to be a good tool to trace the MOW through the Iberian Margin. The comparison of these results with the ε_{Nd} values of core-top foraminifera and sediment samples provides us with enough information to infer how the geochemical signal of seawater Nd isotopes is transferred to the Fe-Mn coatings of foraminifera, and how to interpret these results on a palaeoceanographic context. This study aims to establish the basses to interpret ε_{Nd} reconstructions of MOW changes since the last glacial period in relation with AMOC changes.

Environmental conditions controlling Cold-water corals occurrence in western Melilla (western Mediterranean) since the last deglaciation

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Cold-water corals (CWCs) are widely scattered in the southern Alboran Sea (westernmost Mediterranean), specifically in the so-called East and West Melilla CWC mound provinces (EMCP, WMCP). In this study, we present hydrographical changes in West Melilla from the sediment core MD13-3451 (370 m water depth) across the last ~14.2 kyr BP, followed by an integrated assessment of the WMCP complex evolution. The detected temporal mound occurrence allowed the identification of CWCs development' patterns since the last deglaciation, and relate them to distinct palaeoceanographic changes that potentially influenced the local environment framework. The performed analyses include both sedimentary characteristics (i.e., grain-size records), and geochemical measurements in benthic foraminifera calcite, i.e., stable isotopes and trace elements, such Mg/Ca as a proxy for deep-water temperatures (DWTs). Furthermore, seawater $\delta^{18}O$ ($\delta^{18}O_{sw}$) and seawater $\delta^{18}O$ corrected for the ice volume signal ($\delta^{18}O_{w-ivc}$) have been estimated via paired analyses of Mg/Ca and $\delta^{18}O_{carbonate}$. The generated data suggest: i) CWCs develop well with relatively warm DWTs and high currents intensities, although these factors are here not considered to be determinant in their formation. This also account for the oxygen content, where major changes does not seem to affect CWCs development. ii) Major changes concerning the hydrographical conditions occurred during the Early Holocene, where a rapid freshening of the waters is detected. The presented results, when combined with available records from neighbor sites, permitted to observe that CWCs proliferation or decline is closely coupled to the reorganization of the whole Alboran Sea' water column structure. For instance, the Holocene decrease of CWCs growth occur simultaneously when intermediate water properties above ~400 m water depth became very distinctive from those below, suggesting a higher influence of isotopically lighter water masses. This point to the important role of Mediterranean Circulation in driving the development of coral mounds. Overall, our data provide a high-resolution record of the most recent hydrographic changes in the southern Alboran Sea, and also reflect the importance of integrating a wide range of environmental variables to better understand the complex interplay that controls CWCs development.

Unveiling the variation in intermediate water mass circulation and its potential effects on Tunisian cold-water coral mound development during the last glacial cycle

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To date, most thriving cold-water coral assemblages in the Mediterranean Sea are found within the water depths bathed by the Levantine Intermediate Water (LIW). In a similar way, coral mound development in this basin has been partly linked to the distance between the mounds' summit and the water mass interface found at the transition from Atlantic Water (AW) to LIW (ca. 200-250 m water depth). Water mass interfaces are characterised by sharp density gradients that promote the accumulation of particulate matter, mainly consisting of plankton. Additionally, the interaction between two water masses might promote the creation of internal waves that propagate along the interface, increasing sediment resuspension and vertical mixing, which could ultimately promote enhanced transfer of organic matter to the depths were the corals are found. Nonetheless, due to glacio-eustatic changes and other paleoclimatic variations, the depth and intensity of the AW-LIW interface are likely to change through time. In this regard, the present study aims to use gravity cores collected from on- and off-mound areas of the Tunisian Coral Mound Province to assess the potential variations in intermediate water mass circulation during the last glacial cycle and its effects on coral mound development. Specifically, we aim to use Nd isotopic analyses from both corals and foraminifera to describe the changes of water-mass influence in the area. These analyses will be complemented with grainsize and U/Mn data, extracted from foraminifera, in order to acquire a better understanding of the changes in intensity and oxygenation of the water mass bathing the mounds. The analyses of the samples is currently underway and thus, the preliminary data together with a corresponding discussion will be presented.

Implications of a revised varve-based deglacial chronology from Lago Grande di Monticchio for the Mediterranean region

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Sediment records of Lago Grande di Monticchio have provided detailed insights in global climatic teleconnection patterns. Newly recovered sediment cores (MON16) from this lake provide a new and detailed deglacial record of the mostly varved sediment covering the termination of the last glacial period and the onset of the Holocene. These sediments consist of organic-clastic, diatomaceous, and organic varves that are interrupted by event layers and homogeneous intervals. The detailed stratigraphy of the last deglacial based on micro-facies analyses and XRF core-scanning reveals a stepwise transition from the last glacial into the Holocene. We present a revised chronology based on varve counting, tephra layers, radiocarbon dates, and a novel the Bayesian age-depth modeling approach. The new varve-counting results (CHRON-2022) reveals 8663 ± 123 counted varves, which is clearly more complete compared to previous studies (CHRON-1996). The varve counting results are used to parameterize the priors of the Bayesian age-depth modeling routine Bacon, which integrates both the error of the varve counting and radiometric dating uncertainties into the chronology. The floating chronology was anchored to the tephras of Mercato (8530±100 cal a BP), Pomici Principali (12037 ± 52 cal a BP), and NYT (14194 ± 172 cal a BP). The resulting ages are in good agreement with two radiocarbon dates of plant seeds, whereas three dated leaves revealed too old ages. In addition, the CHRON-2022 chronology revises the age uncertainties of at least 4 of the most prominent tephra layers in the MON16 sediment record. The combination of this varve chronology and tephra isochrons does not only allow to re-evaluate radiocarbon dating in lake Monticchio, but also provides a regional chrono-stratigraphic framework for identical tephra isochrons in the Mediterranean region. Such a regional chrono-stratigraphic framework provides a crucial basis for the reconstruction of regional and global palaeoclimatic teleconnections.

Mediterranean thermohaline circulation variability from the last deglaciation associated with changes in the eastern Mediterranean water outflow

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The Eastern Mediterranean Sourced Water (EMSW) outflow through the Strait of Sicily and together with the Western Mediterranean Deep Water (WMDW) contribute with different proportion to the Mediterranean outflow waters (MOWs) that exit into the Atlantic Ocean through the Strait of Sicily. In this work, we investigate changes in the EMSW outflow from the last deglaciation, with special focus in two periods characterized by important hydrographic changes, 1) The Younger Dryas (YD) and 2) the Last sapropel (S1). For that, we analyze Neodymium isotopes in planktic foraminifera coatings, stable oxygen isotopes and Mg/Ca ratios from both benthic and planktic foraminifera as well as grain-size from a sediment core recovered at the western flank of Sicily channel at 1066 m depth (W-Sicily; NDT-6-2016). At present, this site is located below the hydrographic boundary layer between the eastern and western sourced water-masses and then, it is suitable to evaluate changes in the EMSW outflow. Our data suggests that enhanced and high-salinity flow of eastern Mediterranean sourced waters (EMSWs) during the YD resulted on an intensification of Mediterranean outflowing waters (MOWs) currents. We proposed that this enhanced MOW could have favored the reactivation of the Atlantic meridional overturning circulation (AMOC), which was operating in a weak mode. An important reduction of the EMSW flow during the S1 resulted in a reduced surface Atlantic water eastward flow, reducing its influence at W-Sicily. During the last part of the S1 (S1b) very distinctive hydrographic conditions developed both at surface, with strong mixing, and at depth with the appearance of a high salinity water mass. We propose that regional climate conditions led to an increase of the evaporation/precipitation, which would have favored deep water convection processes, promoting the formation of a high-salinity intermediate-water mass over the Tyrrhenian Sea area during this S1b period.

Last deglacial reorganization of the western Mediterranean thermohaline circulation: evidences from sedimentological and Nd isotopes proxies

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Last glacial/interglacial transition involved significant changes in western Mediterranean (Med) thermohaline circulation that culminated with the formation of an organic rich layer (ORL) in the Alboran Sea from 14.5 to 9 ka BP. This event pre-dated the eastern Med stagnation associated with the Last Sapropel (S1: 10.8-7.1 kyr BP). Here we aim to gain in the understanding that those two events had in the oceanography of the westernmost Med and ultimately its impact on the Med outflow waters (MOW). Our approach combines sedimentological indicators (grain-size and XRF-core scanner data) with Nd isotopes measured in foraminifera diagenetic coatings as a proxy of water mass source. The studied material includes a set of cores covering a depth range from the Alboran Sea (from 300 to 1800 m) combined with a core from the Balearic Basin and another from the Gulf of Cadiz.

Grain-size measurements confirm that major changes in current intensity happened within Heinrich stadial 1. While deepest currents (2400 m) in the vicinity of the Gulf of Lion convection cell became weaker, records from the Alboran Sea show a reinforcement at deep and intermediate levels (1800-600 m) that surprisingly maintained during the whole ORL. During the Younger Dryas Nd isotope values converge along the whole water column, supporting the arrival of more radiogenic waters at the intermediate layer (900-300 m), which are further exported into the Gulf of Cadiz. This event coincides with maximum current speeds above 900 m in the Alboran Sea but also in the Gulf of Cadiz, in agreement with a reinforcement in the arrival of Eastern Med Source Waters (EMSW). In contrast, with the formation of S1 in the E-Med, Nd values between intermediate and deep waters diverge, confirming the reduced influence of more radiogenic EMSW during this period, a signal further exported into the MOW, whose currents reached minimum intensities. These data indicate that during the studied period E and W-Med convection cells changed their operation way compared to the present day and presented an heterogeneous response to deglacial-Holocene climate forcings.

Reconstructing Mediterranean Sea water paleo-pH over different time scales using boron isotopes

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The Mediterranean Sea is considered a climate change hotspot given its relatively small basin size, restricted water exchange connections, and much shorter turnover time than the global oceans. It is especially vulnerable to ocean acidification resulting from the drastic anthropogenic increase in atmospheric CO_2 since the Industrial Revolution. Indeed, instrumental measurements confirm the seawater acidification trend in this basin, not only at surface but in the whole water column. In this context, reconstructing paleo-pH in the Mediterranean Sea is key to understand the evolution of the carbon system and to project future changes in ocean chemistry and climate. In this work, boron isotopes were analysed on planktonic and benthic foraminifera from Mediterranean Sea sediment cores, allowing us to reconstruct surface and sub-surface sea water pH over time. Sample cleaning, preparation, chemical purification and isotopic analyses were carried out at the University of Barcelona. For this, we set up the methodology, including the purification of boron from the foraminifera carbonate matrix using microsublimation, as well as the boron isotopes analysis using a Nu Plasma 3 Multi Collector Inductively Coupled Plasma Mass Spectrometer (MC-ICPMS). We focused on a series of sediment cores from the Strait of Sicily and the Gulf of Valencia, which allowed us to reconstruct pH over different timescales and temporal resolutions: from the last centuries to glacial/interglacial cycles. Preliminary results point towards an acidification trend during the last century, correlated with the anthropogenically induced rise in atmospheric CO_2, and also to pH decreases associated to glacial/interglacial transitions.

Tracking environmental change in Eastern Australia: a multi-lake chrono-stratigraphic approach

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Many Quaternary studies often only utilise single cores to reconstruct environmental change for a given locality lending themselves to a 'single-record' bias. The Thirlmere Lakes Research Program represented a unique sub-surface investigation of the five independent lakes within the Greater Blue Mountains World Heritage area, involving 347m of coring/drilling with over 40 cores collected from the five lakes and deep drilling undertaken on the lake margins and on the alluvial sills adjacent to the lakes. It has involved the development of a robust geochronological framework with 60 optically stimulated luminescence (OSL) and 45 radiocarbon ages, along with a suite of palaeoecological and geochemical analyses. To date, this data set represents the most thoroughly investigated Quaternary sequence in the Sydney basin. The chrono-stratigraphy shows excellent internal consistency with the upper lake sediments comprising 2 – 5 m of organic-rich sediments (thickness of peat varying between lakes) with very low bulk density (0.174 ± 0.103 g/cm^3), very high moisture content (83 ± 9%) and up to 40% total organic carbon (TOC). These organic-rich peaty sediments represent the onset of Holocene climatic conditions and they unconformably overlie a distinct oxidised clastic silty clay that underlies all lakes. This oxidised unit represents a distinctive marker horizon in the lake sediments and also varies in thickness (up to 60 cm) across and within a given lake. This unit has been dated across all five lakes to be 21,000 to 12,000 years (the last glacial maximum [LGM] and the deglacial) and represents a massive hydrological change where Thirlmere lakes dried and the lake sediments were sub-aerially exposed and weathered (oxidised). The oxidised silty clay unconformably overlies older lacustrine sediments that are 60 to 100,000 years in age but the depth of fill and deep-drilling (along with OSL ages) indicates multiple glacial cycles of sediment accumulation. This poster presents the chrono-stratigraphic results, including three master cores using a Bayesian age-depth modelling approach.

The potential of grass phytoliths for palaeoenvironmental reconstruction in northern Australia.

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Phytolith analysis often provides insight into palaeoenvironmental change in regions where other proxies preserve poorly. The highly durable nature of opal phytoliths means that they are highly resistant to a range of environmental conditions, including aridity. Additionally, phytoliths are produced in large quantities by the Poaceae (grass) family and can be differentiated at the subfamily level or below for the reconstruction of grassland dynamics. Since grass subfamilies are closely associated with environmental and climatic conditions, this suggests that grass phytoliths may be potentially useful for palaeoclimatic reconstruction.

Despite this, phytoliths have rarely been utilised as a proxy for palaeoenvironmental reconstruction in Australia, where semi-arid and arid conditions dominate across 70% of the continent. This is partly due to the lack of available modern reference material collections from plant and soil samples. Such collections are time-consuming and intensive to produce but are necessary for establishing relationships between phytoliths and environmental conditions, as well as for accurate phytolith identification and consideration of taphonomy.

This study will develop a modern reference collection of grass phytoliths for northern Australia and will assess the potential of these short-cell grass phytoliths for palaeoenvironmental reconstruction. 36 grass species were collected from across the semi-arid (grassland) and tropical (savanna) zones of the Northern Territory, Australia, and examined for phytolith production utilising both qualitative shape and quantitative size classifications. Relationships with grass subfamilies, environmental factors, and a range of climatic variables are then statistically examined using correspondence analysis. These relationships will be used to assess the potential of grass phytoliths are a proxy for palaeoenvironmental and palaeoclimatic reconstruction in northern Australia.

Radiocarbon dating, dendrochronology and charcoal analysis applied to the relationship between fire and the growth dynamics of the critically endangered Dinosaur tree Wollemi Pine

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In this study we report several lines of evidence, including the radiocarbon dating of wood, dendrochronology, climate assessment and charcoal analysis to consider the relationship between fire events and the growth dynamics of the critically endangered conifer *Wollemia nobilis* (Wollemi Pine). *W. nobilis* was known only from the fossil record until it was rediscovered in 1994 and hence it has been dubbed the Dinosaur tree in recognition of its living fossil status. *W. nobillis* is a tall tree when mature and is located in only a few sheltered locations, approximately 150 km from the city of Sydney, within the Greater Blue Mountains World Heritage Area, Australia. It has been suggested that this restricted distribution is perhaps related to fire, and recent fire events (e.g., The Black Summer fires of eastern Australia 2019-2020) continue to be a challenge for the survival of this iconic species.

Here we present evidence of annual ring boundaries in *W. nobillis*. The methods applied to analyse this species and the identified relationships to climate will be discussed. This demonstrates potential to expand dendrochronological research within a region where other high resolution climate proxies are lacking and instrumental climate data is limited to the last century or two at most. We also synthesise the accumulation of charcoal from 13 sites in the region surrounding Wollemi National Park to provide a longer temporal perspective of fire in this landscape. This data suggests that area burnt has been on the increase over the last ~600 years, and this adds further to the challenges of managing this critically endangered species.

Our work provides both an improved understanding of the growth dynamics of this iconic species and insight into the impact of fire, on the individuals within the population, and in the surrounding landscape. We apply this information to the future management of the remaining Dinosaur trees.

Post-glacial environmental change in the Snowy Mountains, Australia, recorded in a suite of high-resolution lake sediment cores

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Tarns in the highest part of the Snowy Mountains, the only glaciated region in mainland Australia, have captured sediments continuously since deglaciation, ca. 18,000 yr B.P. Analysis of an 8.5 m core collected in 2016 in the largest of these, Blue Lake, demonstrates that the tarns preserve high-resolution, high-fidelity sedimentary records of environmental change since the onset of Termination 1. In particular, the record indicates that south-eastern Australia experienced several dramatic shifts in climate (cold/dry vs. warm/wet) between ca. 18-11 ka, the last two of which may correlate to the Antarctic Climate Reversal and Younger Dryas, respectively. Although the Holocene portion of the core documents a more consistent climate (warm/wet overall), it is punctuated by two notable episodes of somewhat cooler/dryer conditions at ca. 10.8-9.7 ka and ca. 2.2-1.2 ka.
To test and confirm these results, we collected a suite of new cores from two other lakes in the area, Club Lk and Lk Albina, in August 2022. Preliminary analyses of these cores demonstrates that they also preserve detailed, highly structured stratigraphy similar to that in Blue Lake. Although we do not yet have direct age control on the new cores, comparisons to earlier cores indicate that the Club Lake cores span most or all of the Holocene, and the Lake Albina cores extend back to initial deglaciation, equivalent to the Blue Lk core. Because there are multiple overlapping cores from each lake, we anticipate they will provide more robust age models than are available for the Blue Lk core. This in turn will allow us to refine the timing and possible correlations of the events recorded at Blue Lk. Furthermore, because Blue, Club, and Albina all occupy cirques in different drainages, the new cores will allow us to assess local vs. regional influences and coherence of the climatic events recorded in the cores. Full results of our analyses will be presented at the meeting.

The relationship of subfossil diatoms to environmental variables for the fifty lakes on the Burin Peninsula (Newfoundland, Canada).

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Coastal lake ecosystems often vary in such characteristics as salinity, pH, or phosphorous concentrations even at the local scale. This variation influences the diversity of the lake-dwelling organisms, including diatoms, of which remains serve as essential indicators in paleolimnological studies. Although reconstruction of past lake environments can substantially benefit from an application of diatom analysis, such studies require proper data on the relationships of the organisms with their environment, which is seldom available for remote coastal areas. This study aims to establish the relationship of subfossil diatoms to multiple lake water and catchment characteristics on the Burin Peninsula (Newfoundland, Canada). Fifty lakes were surveyed for the measurement of chemical, physical, and morphometric parameters and collection of surface sediment samples in August 2022, which were analyzed for the composition of diatoms and sediment. Although all the lakes are relatively shallow (0.1 – 4.8 m), they differ markedly in other characteristics. For instance, we found a noticeable difference in such characteristics as salinity (0.015 – 28.92 PSU), pH (4.83 – 8.52), or size (0.07 – 43.9 ha), as well as in catchment vegetation. Our results will provide important insights into the diatom compositions in this remote area and their ecological requirements. The obtained data can be further used in the planned paleolimnological studies, focused on the reconstruction of lake ecosystem responses to past marine inundations and climate fluctuations.
The research is carried out as a part of an OPUS project (2020/37/N/ST10/02614) financed by the Polish National Science Centre.

Those chilly Tropics: reconstructing 1,200 yr of climatic and vegetational changes in Nicaragua by creating an ad-hoc Pollen Atlas

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The Pollen Atlas Project aims to understand the effects of climate change and anthropogenic activity on Nicaraguan Dry Tropical Forest by combining botanical surveys, fresh pollen collections, pollen traps and paleoenvironmental reconstruction. The Atlas has been an essential tool for the identification of fossil pollen from a 1,200 yr lacustrine sediment record from El Tigre-Asososca lake (León). This paper will explore the interdisciplinary approach that led to the creation of the PAP, alongside its practical applications and new discoveries. Specific attention will be given to the multi-proxy palynological analysis of El Tigre natural reserve and on those identified taxa that hold the potential of providing new insights into paleoclimatic changes and prehispanic anthropic activity in central Nicaragua. Among all, the identification of various species of *Pinus* in association with *Psidium guineense* unveils a past different landscape and climate to what we see nowadays in central Nicaragua. The Pollen Atlas is freely available on the open-source (https://globalpollenproject.org/) and on social media (https://www.instagram.com/thepollenatlasnicaragua/), and provides information on local uses, ecology, taxonomy and pollen morphology for over 200 species.

Incorporating introduced biota: the changing ecosystem of a Late Neolithic lakeshore community

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A key characteristic of the spread of agriculture into continental Europe is the introduction of new biota. Here, we offer the case-study of the lakeshore, pile-dwelling site of Ploča, Mičov Grad, Lake Ohrid in North Macedonia, to explore how introduced crops and their associated pests were incorporated into Late Neolithic lifeways. A thick organic layer associated with the settlement was extracted through lake cores, as part of the interdisciplinary and international ERC-funded EXPLO project. Within this cultural layer, the waterlogged archaeobotanical remains offer a rich record of human subsistence from the mid-5th millennium BCE, with a main occupation phase constrained by radiocarbon and dendrochronological dating to c. 120 years. The population used a broad spectrum of edible plants including a mix of introduced and native species: cultivated cereals and pulses, oil-seed crops and gathered fruits and nuts. The excellent preservation of the plant remains enables us to consider both the ways by which this population cultivated crops and through which they processed and transformed plant items into plant foods. Lying in a transitional zone between Mediterranean, Alpine and Continental biogeographic zones in the southern Balkans, the site rests within a pivotal, but under-researched region, for understanding the cultural, geographic, and ecological stimuli and barriers underpinning the spread and maturation of early European agriculture.

delta2Hn-alkane and delta18Osugar biomarker proxies from leaves and topsoils of the Bale Mountains, Ethiopia, and implications for paleoclimate reconstructions

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The hydrogen isotopic composition of leaf wax-derived *n*-alkane (delta$^2H_{n\text{-alkane}}$) and oxygen isotopic composition of hemicellulose-derived sugar (delta$^{18}O_{sugar}$) biomarkers are valuable proxies for paleoclimate reconstructions. Here, we present a calibration study along the Bale Mountains in Ethiopia to evaluate how accurately and precisely the isotopic composition of precipitation is imprinted in these biomarkers. *n*-Alkanes and sugars were extracted from the leaf and topsoil samples and compound–specific delta$^2H_{n\text{-alkane}}$ and delta$^{18}O_{sugar}$ values were measured using a gas chromatograph-thermal conversion-isotope ratio mass spectrometer (GC-TC-IRMS). The weighted mean delta$^2H_{n\text{-alkane}}$ and delta$^{18}O_{sugar}$ values range from −186 to −89 per mille and from +27 to +46 per mille, respectively. Degradation and root inputs did not appear to alter the isotopic composition of the biomarkers in the soil samples analyzed. Yet, the delta$^2H_{n\text{-alkane}}$ values show a statistically significant species dependence and delta$^{18}O_{sugar}$ yielded the same species-dependent trends. The reconstructed leaf water of *Erica arborea* and *Erica trimera* is ^{2}H– and ^{18}O–enriched by +55 ± 5, and +9 ± 1 per mille, respectively, compared to precipitation. By contrast, *Festuca abyssinica* reveals the most negative delta$^2H_{n\text{-alkane}}$ and least positive delta$^{18}O_{sugar}$ values. This can be attributed to “signal-dampening” caused by basal grass leaf growth. The intermediate values for *Alchemilla haumannii* and *Helichrysum splendidum* can be likely explained with plant physiological differences or microclimatic conditions affecting relative humidity (RH) and thus RH-dependent leaf water isotope enrichment. While the actual RH values range from 69 to 82 percent (Mean = 80 ± 3.4 percent), the reconstructed RH values based on a recently suggested coupled delta$^2H_{n\text{-alkane}}$ – delta$^{18}O_{sugar}$ (paleo-) hygrometer approach yielded a mean of 78 ± 21%. Our findings corroborate (i) that vegetation changes, particularly in terms of grass versus non-grassy vegetation, need to be considered in paleoclimate studies based on delta$^2H_{n\text{-alkane}}$ and delta$^{18}O_{sugar}$ records and (ii) that the coupled delta$^2H_{n\text{-alkane}}$ – delta$^{18}O_{sugar}$ (paleo-) hygrometer approach holds great potential for deriving additional paleoclimatic information compared to single isotope approaches.

Do Mediterranean deltas behave as alternative state systems? A paleoecological perspective

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Although borrowed to illustrate the impacts of overfishing, the term shifting baselines, or the extent to which each human generation accepts a degradation of the environment and perceives it to be “natural”, can also be applied to other pressing disturbances, such as eutrophication, salinization, and hydrological alteration. This is the case of Mediterranean deltas, where major transformation through agricultural expansion and catchment modification took place during the pre-instrumental era, and hence a long-term vision is needed. In this contribution we will present preliminary results of a combined limnological-paleolimnological approach to characterize multiple shifting baselines in the Ebro Delta (NW Mediterranean). We use a 9800 cal yr BP record to identify feedbacks between proxies for natural disturbances in the delta (pulse events such as lobe switching and climate or fluvial regimes), and ecosystem responses, using XRF techniques and foraminifera community time-series data, respectively. We also compared fossil foraminifera trajectories to a regional data set characterizing the full range of modern communities from marine to deltaic plain habitats, to validate drivers of community change, using a space-for-time substitution approach. Preliminary paleolimnological-scale analyses suggest that following the post-glacial sea level rise, significant peatland-type habitats developed. Thereafter the delta has gone through three ecological states (submerged-vegetated habitats) by crossing two tipping points that marked synchronous changes in both XRF and foraminifera changes. Hierarchical Generalized Additive Models were used to model rate of change and variance which preceded deltaic ecosystem shifts, hence validating their use as resilience loss indicators. Millennial-scale analyses combined with contemporary data provided a robust quantitative framework of habitat regime shifts. The novelty of our paleolimnological-scale resilience analysis is that we should be able to make contributions towards ranking past habitat states in terms of, for instance, sensitivity to variables or combination of variables (sea-level rise, sediment type, salinity) for assessing different lines of evidence for multiple reference baselines at local and regional scales against which to define management and restoration efforts in the Ebro Delta.

Exploring biological responses to climatic change in benthic and pelagic communities during the Holocene within the Arctic region

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The Arctic is experiencing unprecedented (for the Holocene) warming, with increasingly evident impacts on ecosystems of the Arctic Ocean and adjacent seas, as well as physical changes to currents, sea-ice extent and seasonal temperatures. Although a suite of observational datasets for recording these changes has existed for over half a century, longer-term changes in ecosystem stability are harder to quantify. It is vital to constrain changes from a 'natural' baseline, to best predict the future effects of anthropogenic warming. This is also crucial for understanding the positive and negative feedback loops between ecosystems and climate systems in this highly sensitive region. Compilation of multiple palaeoecological datasets over space and time will enable the drivers of climatic change to be characterized, alongside reconstructions of the associated ecological responses to these shifts.

This research presents a compilation of biological proxy assemblages in the Arctic region during the Holocene, with specific focus on the responses of benthic and pelagic communities to different types of climatic change (i.e. abrupt vs gradual). In conditions potentially analogous to the modern-day, meltwater inputs to the Arctic region were common in the early Holocene, as the North American Ice Complex and Eurasian ice sheets melted. These are clearly visible within sedimentological records from the Labrador Sea and Arctic more broadly. Several records also contain multiple proxy time-series of benthic and pelagic communities at high-resolution, predominantly including dinoflagellates, benthic foraminifera and diatoms. The different responses of these communities will be quantified and compared within the same cores, as well as their spatio-temporal distributions within the Arctic region more broadly. This provides a baseline for the biological responses to past climate-driven physical changes within the Arctic region prior to human impact. The spatial component of these analyses may also shed light on the potential extent of meltwater-induced perturbation of different biological communities with implications for future meltwater impacts.

Variations of Primary Productivity in the Northwestern Arabian Sea during the last 23,000 Years and Their Paleoclimatological Implications

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The Arabian Sea (AS) is one of the most productive oceanic regions in the world due to several monsoon-related processes that can increase nutrient contents in the euphotic zone. Previous studies of the imprint of oceanic Primary Productivity (PP) in AS sediments yielded diverse results depending on the studied area and the chosen proxies, with unprecise paleoclimatic interpretations. Here, we provide multi-decennial PP and coastal upwelling dynamic records off northern Oman over the last 23 kyr, based on the analysis of coccoliths from sediment core MD00-2354 (61.48°E, 21.04°N, 2740 m). The last 23 kyr encompasses a glacial-interglacial transition, an entire precessional cycle, and millennial-scale fluctuations in the Atlantic Meridional Overturning Circulation (AMOC) and is therefore a perfect case study to explore the impact of key climate forcing mechanisms on PP for both, past and future climate conditions.

Our results have been compared with previous paleoenvironmental records as well as modelling data (IPSL-CM5 and TraCE-21) to get precise paleoclimatic interpretations. We document higher PP and weaker coastal upwelling during the Last Glacial Maximum (23–19 ka) relative to the Holocene, and significant millennial-scale variations over the last deglaciation (19–11 ka) corresponding to the fluctuations of the AMOC strength. Higher PP and weaker upwelling are found during the cold stadials Heinrich Stadial 1 (17–14.8 ka) and Younger Dryas (12.9–11.8 ka), while lower PP and stronger upwelling during the warm period Bølling–Allerød (14.8–12.9 ka). We propose that the increases of PP were driven by increased bioavailable nutrient content in surface waters under both, stronger winter monsoon conditions that strengthened the convective mixing, and higher aeolian inputs. Over the Holocene, stronger upwelling and slightly lower PP are found during the Early-Mid Holocene (10–8 ka), when higher summer insolation triggered stronger summer monsoon. At that time, the lower PP was probably the result of restricted advection of summer upwelling seawater under negative wind stress curls and less aeolian inputs.

Holocene vegetation, climate and human impact in the mid-Kama region (pre-Urals, Russia)

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The Ural Mountains form a unique bioecological and climatic border between Europe and Asia, simultaneously uniting them by cultural, ethnic and economic relations throughout history. To shed light on the natural and land use history of this region in high temporal resolution, we obtained a seven-meter peat core Shabunichi-I from the Paltinskoe peatland located on the fluvial terrace of the Middle Kama River Basin (Perm region, Russia). Here we present the new results from palaeoecological studies of vegetation, fire and settlement history over the last 9200 years based on AMS radiocarbon dating, loss-on-ignition, macro-charcoal, pollen and non-pollen palynomorphs. In our study we focus particularly on the Iron Age when human impact on the natural environment in the region increased due to a significant rise in the number of settlements. Since 9200 cal yr BP, the vegetation was presented by Siberian taiga and forest-steppe. The vegetation along with frequent local fires testify to the dry climate in the early Holocene. By the mid-Holocene, the spread of spruce and broad-leaved species together with the absence of a local fire signal indicate the humification of the regional climate. Since 4000 cal yr BP, the maximum expansion of broadleaved species is combined with the appearance and spread of Siberian fir. Signals of anthropogenic changes in vegetation are marked in the pollen assemblages since the Bronze Age (~3900 cal yr BP). However only since ~2000 cal yr BP, the vegetation dynamics was strongly influenced by anthropogenic activity and human-induced fires. Archaeobotanical data from archaeological excavations are in line with palynological investigations, showing that the Iron Age cultures practiced agriculture with barley and emmer and gathering of wild plants such as raspberries, strawberries and elder. Wood anatomy studies provide new insights in selective usage of wood, showing use of linden and birch for artifacts production and charcoals of Scots pine and spruce in burial rituals.

Changing organic carbon sources in the Chukchi Sea sediments with sea ice retreat over recent centuries

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Assessment of sources and burial of organic carbon in Arctic sediments and their temporal evolution with sea ice retreat is important to better understand the alteration of the organic carbon cycle and its impact in the Arctic Ocean region and the global carbon budget. Here, we characterize the major sources of organic carbon in sediments using bulk organic parameters and highly branched isoprenoids (HBIs) in surface sediments across the western Arctic Ocean. Sympagic, pelagic, and terrestrial sources were characterized using HBIs, sterols and bulk parameters (total organic carbon, total nitrogen, $\delta^{13}C_{org}$, and $\delta^{15}N$).

Then, downcore profiles were generated to explore compositional changes of organic matter and how they have been affected by retreating sea ice over the last two centuries in the northern Chukchi Sea. We found that the organic carbon pool was mainly constituted of land-derived material under severe sea ice conditions, which has been decreasing from the 19th century onwards with shrinking sea ice as indicated by rising sympagic and pelagic organic carbon, in particular in the last decades when sea ice decline accelerated.

A comparative study of Cultural Interactions between Harappan and Jiroft Civilization in middle of the 3rd Millennium BCE

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Harappan Civilization (HC; Indus River) is a well-established culture, with multiple stages of cultural groups coexisting in large regional urban centres in Pakistan (i.e., Harappa, Mohenjo-daro) and India (i.e., Rakhigarhi and Dholavira), spread over the northwestern part of the South Asian region dated from 2600 to 1900 BCE. It was distinguished by systematic town planning, intricate drainage systems, granaries and the standardization of weights and measures. Simultaneously, another culture flourished in Iran called Jiroft Culture (JC; Halil River) during the same period. So the important research question is whether those cultures (HC and JC) had any connection or any similarities. This research aims to understand the cultural affiliations between JC and HC and study these connections with special reference to glyptic art on the seals that has been used to unravel the interactions.

The present research is based on the newly excavated materials from Halil River Basin and earlier reports retrieved from cultural materials of both the civilizations. To achieve this goal, a closer look has been taken at the iconographic scheme and the techniques of depicting the symbols and other visual elements on the seals during the 3rd Millennium BCE. The result shows different kinds and size of stamp seals (mostly made on Bronze, Terra cotta, Alabaster and White stone) and also some wares which were found in both the civilizations. In addition, the motifs on the Unicorn, Zebu bull and crocodile symbols which were found in Iranian stamp seals were known to be found only in HC. The depiction of similar kind of animal symbols found in both the civilizations show that they had some shared connection through trading relationship via the possible sea and land routes during the time.

The research will focus on these icons, symbols and an attempt has been made to understand the exchange of ideas and thoughts across the huge span of landscape covering the present-day Indian sub-continent and the Iranian Plateau. These results will bring new discovery of antiquity and show how cross-cultural interactions happened between the aforementioned two highly complex urbanized systems.

Poster - sessions 19, 29, 40, 44, 58, 67, 123, 141, 143, 154, 159, 197

The ANR QUARTZ project: A multi-method approach for quartz characterisation in alluvial sediments for source-to-sink tracing and dosimetry

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The Critical Zone is exposed to a multitude of external forcings (including climate) that condition its environmental evolution and available resources. Understanding the geological processes behind these changes is a challenging task.

Alluvial systems are the response to intertwined climatic, tectonic, (palaeo-)geographic and anthropic drivers over the last millennia, being in consequence very suitable proxies for the Critical zone. The characterization of alluvial sediments, which provide valuable information about the environmental conditions at the time of their deposition. allows indirect assessments of these drivers.

Against this background, quartz mineral is an ideal tracer of the alluvial system's evolution because of its ubiquity and absence of strong weathering. Quartz are also characterised by some differences in their composition and behaviour in response to various stimuli (light, irradiation, ...) related to its initial conditions of formation, and perhaps also to its sedimentary history.

In the ANR QUARTZ project, we aim to develop a multi-technique methodology that uses quartz grains as markers of sedimentary dynamics. The ANR QUARTZ project explores (i) how each quartz grain holds a source-specific signature, and (ii) how this signature evolves over time across sediment routing systems. This 3-year project started in December 2021 and focuses on three French river catchments draining the Vosges, the Alps and the Massif Central: the Strengbach, Séveraisse and Creuse, respectively. Modern river borne sediments from the main trunk and tributaries, along with bedrock sources, were extensively sampled in the two first catchments. River terraces of the third catchment will be sampled in 2023.

In this project, the luminescence and paramagnetic properties of the river sediments will be studied along with their elemental composition. The variations in quartz grain characteristics will help to estimate evolution over time of their origin(s) and mode of transport as well as the response of the system to external changes, including volumes of sediments transported from a source-to-sink perspective.

Deciphering the Rates and Dynamism of Glacial Erosion in Alpine Catchments Through a Novel Application of Thermoluminescence Thermochronometry

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Mountain landscapes across the Earth have been profoundly shaped by periods of successive glaciation, creating unique landforms such as U-shaped valleys, cirques, aretes and large bedrock steps. These features can significantly impact the behaviour and evolution of mountain glaciers and suggest a strong spatial variability to glacial erosion.

Previous research on the spatial and temporal dynamics of glacial erosion have largely been confined to the study of cirques and headwalls, or through topographic study of landscape hypsometry, whilst the dynamism of catchments and glacial profiles as a whole have been explored conceptually within numeric models. Erosion is commonly modelled numerically in a simplified relation to ice sliding velocities based on limited observations and data, which has led to a variety of proposed exponent values. As such, there is a continuous need for empirical evidence of erosion rates at the sub-catchment scale in order to better constrain the dynamic variability of erosional processes throughout the catchment profile and to test hypotheses derived from topographic and numerical analysis.

By applying a method of thermoluminescence thermochronometry (TLT), we can begin to explore the near-surface cooling history of bedrock as it is exhumed by processes such as glacial erosion. We target feldspar minerals in samples of exposed glacially-eroded bedrock along the profile of contemporary glacial catchments in the Swiss Alps. By exploiting the novel ability of TLT as a very low temperature thermochronometer we can decipher rates of glacial erosion throughout these catchments over 10 ka timescales.

Combined with landscape evolution modelling using the integrated Second Order Shallow Ice Approximation (iSOSIA), we can gain insight into the spatial and temporal rates of glacially-induced landscape evolution backed by empirical data. Further, this can be used to test different numerical laws for glacial erosion by combining TLT data and ice sliding velocities.

Finding Quaternary Seismogenic Activity along the Eastern Periadriatic Fault System: Dating of Fault Gouges using Trapped Charge Methods

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The Periadriatic Fault System (PAF) is among the most important and largest post-collisional structures of the Alps; it accommodated between 150-300 km of right-lateral strike-slip motion between the European and Adriatic plates from about 35 until 15 Ma. Recent GPS data suggest the Eastern Alps are still accommodating Adria-Europe convergence. However, according to instrumental and historical seismicity, seismotectonic deformation is mostly concentrated in the adjacent Southern Alps. In this contribution, we aim to show which segments accommodated seismotectonic deformation during the Quaternary by applying Electron Spin Resonance (ESR) and Optically Stimulated Luminescence (OSL) dating to fault gouges produced by the fault system. The method is especially useful for dating shear heating during earthquake activity at near-surface conditions due to its dating range (a few decades to ~1 Ma) and low closure temperature (below 100°C). For ESR, we measure the signals from the Al center in quartz following the single aliquot additive (SAAD) and single aliquot regenerative (SAR) protocols, focusing on the 100-150 µm grain size fraction. For OSL, we use the SAR protocol and measure the infrared stimulated luminescence (IRSL) signals at 50°C and 225°C on potassium feldspar aliquots of the 100-150 µm grain size fraction. Our ESR results indicate the PAF system accommodated seismotectonic deformation during the last 1 Ma, while the minimum ages obtained via OSL suggest that the events are not likely younger than 0.4 Ma.

Deciphering Past Desert-Margin Dynamics in Matmata, Tunisia

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The terrestrial dust archives around Matmata (Tunisia) are unique in their morphological setting and grain-size composition. Located in front of the Grand Erg's in a critical zone at the northern edge of the Saharan desert, up to 35 m thick plateau-like loess accumulations cover past landscapes. Sandy loess and intercalated palaeosols attest to rapid and large-impact climate boundary shifts. Some of them may have severely threatened ancient regional cultures, and future changes may put modern settlements and agriculture projects in the region at risk. Palaeolandscape reconstruction, supported by reliable chronologies, charts past and predicts possible future scenarios.

The 'desert-loess' records around Matmata seem to engulf a wide temporal range back to Marine Isotope Stage (MIS) 9. Trapped charge dating techniques, such as luminescence and electron spin resonance (ESR) dating, are versatile tools for deciphering the timing of past landscape changes in this area. We provide new luminescence (Infrared-Radiofluorescence, optically stimulated luminescence) and electron-spin resonance dating results from seven different sites and attempt to link our findings to regional climate fluctuations and drainage alterations observed for the large endorheic salt lakes in the Matmata plateau's close purlieu.

Detection of the bomb peak 14C for the onset of the Anthropocene

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The unprecedented environmental changes resulting from anthropogenic activities initiated during the Great Acceleration of the mid-20th century can be traced using radiocarbon analysis. The cosmogenic isotope ^{14}C, which is produced in the atmosphere, is well-known as the geochronological tool applied to archives of the last 55 thousand years. However, during the last 200 years, the natural signal of ^{14}C in the atmosphere and connected reservoirs (biosphere, ocean, soils, etc.,) has been perturbed by human activities. Two anthropogenic effects are observed: a decreasing trend observed in ^{14}C concentration of the atmosphere (Suess effect) which has been temporarily reversed by aboveground thermonuclear tests of 1950/60s.

The excess of the artificially produced ^{14}C (bomb pulse) is a useful time marker for the mid-20th century and the detection of the bomb peak in natural archives has thus been proposed as a tool to locate and date the onset of a proposed new epoch, the Anthropocene.

Here we present the results of radiocarbon analysis conducted as a part of the research dedicated to establishing the Global boundary Stratotype Section and Point (GSSP) for the proposed Anthropocene. The studied sites include corals (Flinders Reef, AU and Flower Garden Banks, USA), peat (Śnieżka peatland, PL), lake sediment (Crawford Lake, CA and Searsville Lake, USA), and marine sediment (East Gotland Basin, Baltic Sea). The variety of records (different carbon reservoirs) required site and sample-specific treatment prior to analysis and site-specific interpretation of the measured ^{14}C. Nevertheless, the mid-20th century bomb peak was detected at all but one site. In all records, the observed onset of the ^{14}C bomb peak always postdates 1954, the year of the first atmospheric ^{14}C bomb increase. The specific reservoir effects and corrections will be discussed.

A Siderastrea siderea Coral from Flower Garden Banks Records Human Impacts as a Candidate for the Global Boundary Stratotype Point for the Anthropocene

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Corals are unique in the suite of proposed Anthropocene Global Boundary Stratotype Section and Point (GSSP) sites since they are living organisms that produce aragonite exoskeletons that can be preserved in the rock record. Corals also contain highly accurate and precise (<±1 year) internal chronologies, similar to tree rings, that can be confirmed by high-precision uranium-thorium dating. The proposed Anthropocene GSSP candidate site of West Flower Garden Bank (27.8762°N, 93.8147°W) is an open ocean location in the Gulf of Mexico with a submerged coral reef and few direct human impacts. Here we present results from a large *Siderastrea siderea* coral (core 05WFGB3; 1755–2005 CE) sampled with annual and monthly resolutions that show clear markers of global and regional human impacts. Atmospheric nuclear bomb testing by-products have clear increases in this coral starting in 1957 CE for ^{14}C and the first increase in 1956 CE for $^{239+240}Pu$ (potential bases for the Anthropocene GSSP). Coral $\delta^{13}C$ declines especially after 1956 CE consistent with the Suess Effect resulting from the burning of fossil fuels. Coral skeletal $\delta^{15}N$ starts to increase in 1963 CE corresponding with the increase in agricultural fertilizers. Coral mercury concentrations (1933–1980 CE) loosely track fluctuations in industrial pollution and coral Ba/Ca increases from 1965–1983 CE when offshore oil operations, which use barite, expanded after 1947 CE. Temperature proxies (coral Sr/Ca) contain the 20th-century global warming trend whereas coral $\delta^{18}O$ reveals an increase in salinity. Furthermore, coral growth declines during this interval. As the scientific community debates the GSSP site, year, and marker for the start of the Anthropocene, coral reefs are projected not to survive. Yet corals will continue to record their last years in their skeletons, passively archiving the changes in their environment, chronicling the stressors, pollutants, and damage done to these otherwise multi-centenarians living organisms.

Ecosystem and human responses to recurrent climate changes at the Pleistocene-Holocene transition in the Scheldt basin (southern North Sea area, NW-Europe)

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The last decades intensive high-resolution interdisciplinary research into the Late Glacial and Early Holocene in the Scheldt basin of Belgium, northern France and southern Netherlands has provided new insights into the ecosystem and human responses to successive climate fluctuations, both warming (GI-1e, GI-1c, a, and Early Holocene) and cooling (GI-1c2, GI-1b, GS-1, and Holocene IRD-events). Evidence suggests that while environment became more attractive to humans during the warm episodes, as a result of the denser and wider availability of wild resources and freshwater, they temporarily were confronted with stress situations due to increased wildfires and fluctuating water levels in lakes, ponds and rivers. In addition they had to face the consequences of repeated short but abrupt cold reversals which led to a temporal opening of the landscape (increase of herbs, grasses and sedges), a reduction of thermophilic plants (e.g. hazel) and renewed aeolian activity, the latter transforming the landscape (dune migration, infilling dune ponds and lakes). In my presentation I will highlight some of these environmental changes and the associated human response, ranging from decreased population density, over adaptation of the hunting equipment to changing mobility and land-use.

Deforestations, tribe to state transition and Cistercians impact on nature - a high-resolution multi-proxy 1000-year's record from the Eastern Germany kettle-hole peatland

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Peatlands are exceptional archives; they store information about climate and human impact. Recently, our focus has been placed on the critical transition connected with the loss of pristine ecosystems in the last millennium. Several sites in western Poland show distinct patterns associated with deforestation and fires triggered by Europe's rapidly developing economy and population growth. The new study aimed to fill the gap in the high-resolution palaeoecology of Central Europe using the peat archive of a well-preserved Sphagnum-dominated kettle-hole located in Eastern Germany. Based on the former studies, we hypothesized that deforestation related to Cistercian's' economic impact triggered cascading effects on the peatland ecosystem leading to hydrological instability.

Furthermore, we aimed to date the tribe-to-state transition and loss of old growth forests leading to landscape openness and the arrival new economy supported by Christianity. First data show a clear shift linked to the local land-use changes and increasing fires ca 1300 CE. At this time, there was a transition to grazed woodlands, as indicated by the high proportion of oak pollen (up to ca. 40%) with the simultaneous high landscape openness and more substantial human impact. This impact is also visible in the taxonomic change of testate amoebae and the appearance of *Criptodifflugia oviformis*, and the decrease of mixotrophic species such as *Hyalosphenia papilio* and *Archerella flavum*. Our study shows that deforestation led to water loss on pristine peatlands. In the future steps, we aim to correlate palaeoecological signals to the historical events and economic increase in Eastern Germany.

Late Pleistocene and Holocene Caribbean mangroves: responses to climatic, eustatic and anthropogenic drivers of ecological change

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Mangroves are keystone ecosystems, as they provide habitat for many terrestrial and marine species and are globally linked via atmospheric processes, participating in the global carbon cycle as an important carbon sink. Currently, mangroves are among the world's most threatened ecosystems. Since the 1980s, these forests have experienced a global cover loss by deforestation of 25-30%, which would lead to their disappearance within the next century. Major threats are agriculture, aquaculture, wood extraction, urbanization and global-warming-driven effects, such as sea level rise, increasing extreme weather events or invasion by alien species, among others. Understanding how mangrove ecosystems respond to natural and anthropogenic drivers of change is essential for informing conservation and restoration practices. In this sense, the responses of mangroves to climatic, eustatic and anthropogenic pressures of the last centuries and millennia may be of great utility, as they provide a natural laboratory where to study the potential effects of the main threats. This work reviews the available multiproxy information, with emphasis on palynological records, for Late Pleistocene and Holocene times in the Caribbean region. The first records date from the Last Interglacial (Eemian; MIS 5e) when global average temperatures and sea levels were slightly higher than the present and mangroves grew in locations and conditions similar to today. During the Last Glaciation (Weichselian; MIS 5d to MIS 2), SSTs and sea levels were ~4°C and 80-120 m below the present, respectively, and Caribbean mangroves were far from their present locations, especially in areas with shallow and extensive continental shelves. Caribbean mangroves progressively attained their present configuration during the Late Glacial-Early Holocene warming and sea-level rise, in the absence of anthropogenic pressure. Human influence began to be important in the Mid-Late Holocene, especially during the Archaic and Ceramic cultural periods, when sea levels were already at their present heights and climate-human interactions were the most influencing factors. During the last millennium, the most relevant drivers of ecological change have been the episodic droughts linked to the Little Ice Age and the European contact and their further consequences.

The ups and downs of Polish statehood - paleoecological insights from Lake Lednica (western Poland) during the last 1500 years

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Greater Poland, which is the historical region of west-central Poland is regarded as the center of the emerging Polish state in the 10th century. However, the settlement and its time frames before the formation of the center of power related to Piast's dynasty in this region are poorly explored. Therefore, paleoenvironmental reconstructions of high chronological control could increase knowledge about past societies' economic activity and related environmental transitions. In this study, we analysed a 2-meter long profile from Lake Lednica (in the central part of Greater Poland) for pollen, selected coprophilous fungi, microcharcoal, geochemical composition via µXRF scanning, and grain-size distribution supported by 24 AMS radiocarbon ages. The aim was to explore the impact of socioeconomic processes on the local environment.

The results show the regeneration of oak-hornbeam forest from the end of the 5th century. It was a time of low human impact, however, sufficient for a gradual selective hornbeam clearing, as reflected by *Carpinus betulus* pollen decline from ca. 580 cal. CE. The largest environmental changes associated with intensive human activities took place from ca. 850 cal. CE and were probably related to the formation of power centres around Lake Lednica (or on its islands). We observed during that time increase in Fe/Mn ratio, indicating anoxic bottom water conditions in the lake, possibly caused by increased nutrient supply to the lake.

Since then, a decline in arboreal pollen and a rise in ruderals as well as cultivated pollen are recorded. Moreover, since ca. 940 cal. CE Fe/Mn ratios show a distinct peak that could be related with construction of bridges between 963 and 964 CE connecting the island to the mainland.

After 1050 cal. CE, a sharp decline in cereals pollen is recorded, which was probably related to the Bretislav invasion recorded in 1039 CE and led to depopulation and massive damage of strongholds including Ostrów Lednicki. This condition lasted until around 1300 cal. CE, when a return to the pre-crisis state started. Rapid deforestation and an increase in agriculture were recorded from around 1450 cal. CE, which was probably related to the establishment of surrounding villages.

Human-environment interactions at the central Mediterranean site of Motya (Sicily, Italy)

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The island of Motya, found in the Marsala lagoon in western Sicily, has been the object of archaeological excavations by "Sapienza" University of Rome for over 60 years. Known for its Phoenician occupation (8^{th} century – 397 BC), the small island (ca. 40 ha) was inhabited since the 17^{th} century BC.

Systematic archaeological studies have been integrated with multi-analytical approaches in the fields of archaeozoology, petrography and metallurgical techniques. The more recent introduction of archaeobotanical and palynological studies has allowed to expand our knowledge of the use of plants by the past inhabitants of Motya, complementing archaeological information with data concerning diet, food and flower offerings, land exploitation, past vegetation, environmental changes, and the introduction of plants from other areas of the Mediterranean. Pollen data describe an open environment, with scarce tree cover and characterized by complex anthropic activities. Anthracology shows a prevalence of Mediterranean taxa, such as *Quercus* evergreen, *Pistacia lentiscus*, and *Olea europaea* throughout the studied period. In terms of land exploitation, both disciplines support the archaeological hypothesis that *Vitis vinifera* was cultivated on site, also suggesting an abundance of olive trees. Furthermore, the presence of chaff and different sized weeds, as well as cereal pollen indicate local crop processing. As far as diet is concerned, a preference for barley can be seen in pre-Phoenician Motya, gradually integrated with naked wheats from the 8^{th} century onwards. Interesting is the introduction of *Punica granatum* (pomegranate) from the East, previously hypothesized based on the find of a globular pottery vessel with an indented rim resembling the fruit, which was confirmed by the retrieval of six exocarp fragments in a disposal pit (8^{th} - mid-6^{th} century BC). Other plants likely introduced to Motya by Phoenicians include *Juglans regia* and *Pinus pinea*. Additional considerations can be done concerning grapes and wine. While the vast repertoire of Phoenician and Proto-Corinthian drinking vessels indicates wine consumption at Motya, and tartaric acid has been detected in dental calculus of 6^{th} century BC Phoenician inhabitants of the island, morphometric analyses of *V. vinifera* seeds allowed to obtain preliminary results concerning the consumed grape varieties.

Coastal resources in Fuego-Patagonia's Paleodiets: a micro-scape and temporal stable isotope approach.

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Fuego-Patagonia (46-52° S), the southernmost region of the Americas, has a long history of human occupation (~10,500 BP-present), which is characterized by the presence of groups that utilized coastal resources to varying degrees. In Fuego-Patagonia, stable isotope (SI) analyses have been used to identify the dietary contribution of coastal resources among pre-contact groups. The identification of coastal resources in the diet, and the estimation of their dietary contribution, has been characterized by a broad approach but does not consider SI variability within the same species in time and space. The current study analyzes SI data collected from coastal resources (e.g. seals, sea lions, penguins, shellfish, fish, and cormorant) recovered at archeological sites in Fuego-Patagonia. We also include some plant remains known to be part of historic diets. To identify micro-scape and temporal differences in these resources' stable isotope signature, the archaeological sites and SI data are organized into two periods (Middle vs. Late Holocene), and ten areas distributed from the Atlantic Ocean' to the Pacific Ocean' shores, including areas located along the Magellan and Beagle Straits. Analyses indicate significant differences in the SI of resources by area. When human dietary reconstructions are conducted considering this variability, the results strongly indicate that these interpretations must consider micro-scape variabilities of resource species, which could also contribute to our understanding of human mobility patterns, and the changing interaction between humans and their environments. Future studies could also benefit from this approach, and further enrich our understanding of the flexible strategies used by hunter-gatherer groups in the past. Our analyses re-affirm that any conclusions drawn from Bayensian analyses to identify past isotopic niches must consider the lack of visibility/identification of foods that preserve poorly in the archaeological record may lead to incomplete or misleading dietary reconstructions.

An integrative approach of soil mapping, geophysical surveys and historical accounts to locate a 14th century plague mass grave in Erfurt, Germany

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In the 14th century, Central Europe was struck by several catastrophes, leading to a prolonged state of socio-economic and agrarian crisis. Among these events were weather-induced crop failures that caused the largest famine in European history – known as the Great Famine (1315-21) – and the Black Death pandemic (1346-53), extinguishing 30-50% of Europe's population. For the city of Erfurt in Thuringia, substantial human losses and corresponding mass graves in nearby deserted villages are well-documented for the two events in historical archives. Erfurt is therefore a unique place to study both fatalities and to explore their possible links to one another, and to destabilizing climates towards the onset of the Little Ice Age. In this pilot study, funded by the German Research Foundation (DFG), the first priority lies on the localization of the mass graves in order to advance our future archaeological, anthropological, archaeogenetic and palaeoenvironmental research.

Here we present our integrative approach of historical, pedostratigraphical and geophysical investigations to identify the location of a Black Death cemetery in the deserted village of Neuses, municipality of Erfurt. Within the area of interest (AOI), constrained by historical accounts and GIS implementations, we applied vibracoring (n = 56, ≤ 5m coring depth) and near-surface geophysical methods (electrical resistivity tomography and ground-penetrating radar).

Combined geophysical and coring sections help elucidate the late Quaternary sedimentary processes and allow for the designation of pedogeographical units as an essential natural background for more detailed geoarchaeological prospections. Two such pedogeographical units delimit each other within the AOI and display consistent stratigraphical and pedogenic sequences: (1) a *Chernozem* zone and (2) a *Black Floodplain Soil* zone. Conceivably, the distribution and extent of these zones co-determined the positioning of the former village Neuses and its presumed associated Black Death cemetery. Based on that, our set of methods enabled a preliminary reconstruction of the medieval subsurface architecture within the AOI, despite large-scale ground modifications carried out there in the 20th century. A few of the identified buried structures have a high potential of representing an actual mass grave due to their sizable dimensions. This will be clarified during upcoming excavations.

Landscape evolution in Central Macedonia (Greece) during the last four millennia

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Balkan vegetation and climate have shown a great variability during the last 4 millennia. Ecosystem richness and geomorphological variability of the habitats have been continuously shaped by human societies but are also susceptible to environmental and climate changes. Within this, Central Macedonia (Greece) is characterized by complex vegetational and historical dynamics. The present landscape is the result of cultural, political, and socio-economic factors and environmental evolution over thousands of years.

Landscape reconstruction based on two natural archives, Paliouras lagoon and Volvi Lake, are herein palynological studied and compared to offer a new and detailed assessment of the last 4000 years history of Central Macedonia.

Pollen results reveal an environment dominated at regional scale by shrubs and trees of the mediterranean vegetation with the predominance of evergreen oaks that characterized the arboreal cover of the two sites. The replacement in the last centuries of thermophilous mixed forest with xeric-adapted taxa at Paliouras are influenced by both climatic and human factors. Instead, human impact is the main reason behind the opening of the landscape and the reduction of arboreal vegetation in the last millennia at Lake Volvi. Agricultural activities are evidenced by the presence of cereals (*Avena/Triticum* group, *Hordeum* group and *Secale)* and cultivated trees (e.g., *Juglans* and *Castanea*) and intensified during the Roman rule of the region. The wide presence of weed and ruderal taxa such as Cichorieae, *Plantago lanceolata, Rumex* and *Galium*, highlights herding as the main human activity in both areas. The palaeoenvironmental reconstruction has been flanked by a punctuated study of written sources for the surroundings of the two sites that give a detailed picture for the Byzantine and Ottoman periods. The increase of human activities in the last centuries of the Byzantine empire and later with the Ottoman rule is driven by both agriculture as well as animal husbandry as evidenced in the pollen record. High-resolution pollen data and historical sources revealed an altered landscape associated with land-use changes according to the historical events in the region. Late Holocene climatic fluctuations have contributed to modify the environment and had spillover on society and land management.

Intensive anthropic activity in Central Spain as driver of vegetation turnover: the pitch kiln evidence of Sierra de Gredos

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Forest products derived from resin, such as pitch or tar, have played a crucial role in past societies for many centuries. Research in the Gredos Mountains (central Spain) has revealed the existence of a dense network of pitch kilns at the 1200-1800 m asl altitudinal interval. Intensive efforts have been made to locate these structures in the central section of the Massif, where more than 50 kilns have been identified, showing a high density of these archaeological structures. In most of these kilns, charcoal have been recovered for anatomical study, showing extensive evidence of the use of *Pinus* gr. sylvestris as the main fuel source. Radiocarbon dating has provided Holocene dates for the Pinus charcoal remains (ca 400 -1200 cal AD). Palynological data, as well as macrofossils and charcoals from soils have revealed the dominance of pine forests in these mountains during most of the Holocene, with a significant disappearance in the last 1,500 years. Climate, grazing and the increase of the use of fire have been suggested as the principal causes of the forest demise and the subsequent dominance of today's fire-prone scrubland. The data presented here, together with other historical and toponymic information, suggest that human activities in mountain areas included intensive industrial practices, not only in the Gredos Mountains, but also in other subcontinental sierras of Iberia. It also shows that tar extraction may have played an important role in shaping mountain vegetation in Iberia during the late Holocene.

Simulation of past agricultural landscapes in Konya Plain coupled with changing climates and communities

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The Konya Plain, located on the Anatolian plateau, has always been an important agricultural production center, for the communities and civilizations which settled in the region since the Neolithic (ca. 12,000 cal. BP). Past agricultural practices and climatic conditions have cumulatively shaped the current vegetation and landscape of the region. The region faces remarkable ecological problems today such as salinization, aridification, and excessive groundwater use for irrigation. The plain's current ecological vulnerability and abundance of archaeological settlements in the area have increased scholarly interest. Despite numerous paleoenvironmental and archaeological studies in the region, achieving a temporally and regionally integrative and long-term dataset is tricky. First, this research aims to reveal the climatic changes in the region throughout the Holocene quantitatively. Macrophysical Climate Model (MCM) and CHELSA-TraCE21k dataset were used to obtain the paleoclimate in the region numerically. Second, it seeks to comprehend how agricultural production and landscape have evolved along with regional climatic and social changes. In this study, archaeological evidence, paleoclimatic reconstructions, and historical records from the region were integrated, and past agricultural production was simulated using agent-based modeling (MedLanD). MedlLanD Modelling Laboratory is a hybrid modeling platform that simulates long-term socio-ecological transformations regarding agricultural production and landscape evolution. Preliminary findings from the MCM point to the wetter and warmer periods in the Early Holocene, similar to isotope proxies in the region. Precipitation declines at the end of the Early Holocene, and the Middle Holocene has drier climate conditions. Although the MCM and CHELSA-TraCE21k data present similar temperature values, there are significant differences between precipitation values. Due to this variation in precipitation values, the model results were compared with the proxies and evaluated. Using the MedLand model and climate data, base maps (i.e., digital elevation, bedrock, soil depth, vegetation maps) for modeling agricultural production were created, and test runs for various time periods were performed. In the advancing parts, this research will be focusing on select periods, which represent cultural (i.e., the emergence of complex societies) or environmental (e.g., increased aridity or higher anthropogenic impacts) challenging phases in Konya Plain.

Local ecological consequences of the Black Death against background regional post-pandemic changes – the case of the Szurpiły settlement micro-region, NE Poland

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The Black Death (AD 1347-1352) was the most renowned pandemic in human history, believed by many to have killed half of Europe's population. However, our knowledge of the Black Death remains limited, based primarily on qualitative remarks in medieval written sources available for some areas of Western Europe. A. Izdebski and co-authors recently presented a new approach to this issue, using palynological data to evaluate the Black Death's mortality on a regional scale across Europe. This study shown that the Black Death had a devastating impact in some regions, while it had negligible or no impact in others. The picture of regional environmental changes in a consequence of the plague is, however, a considerable "unification" of local data. In our opinion, in the case of some settlement microregions, the local changes caused by the pandemic could be significantly different from those reconstructed for larger regions to which they belonged. To prove this, we present high-resolution pollen data from annually laminated sediments of Lake Szurpiły located in NE Poland – for this region A. Izdebski and co-authors suggest post-pandemic agrarian growth, reflecting limited Black Death mortality. Our data document almost complete disappearance of anthropogenic plant communities and significant reforestation of the studied lake vicinity already at the transition of the 11th and 12th centuries, long before the outbreak of the epidemic. This event is well correlated with reconstructed by F.C. Ljungqvist cooling on the extra-tropical Northern Hemisphere, which was the first signal of the coming Little Ice Age. Thus, Black Death encountered an area around Lake Szurpiły that was very sparsely populated (low values of human pollen indexes) and covered with dense forest (high proportion of tree pollen). This state of affairs lasted until the middle of the 16th century and the colonization during the reign of the Grand Dukes of Lithuania. In the palynological record, the only signal of Black Death-induced mortality is the proportion of human pollen indicators noted in a sample dated at ca. AD 1350, which is the lowest in the entire profile.

The lacustrine record of the Anthropocene in central Chile

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Human driven Global Change has widely impacted Earth System dynamics at least since the industrial revolution and particularly during the Anthropocene Epoch. Although such impacts on terrestrial ecosystems, surface processes, biogeochemical cycles and climate have become stronger during the last century, it is likely that these have occurred at variable intensities since long time ago. These human activities have had important effects not only in the terrestrial ecosystems, but also in the aquatic ecosystems due to the hydrologic linkages between both. For this, lakes are important sink of sediment from its basin and plays a key role for environmental reconstructions. Here, to improve our knowing about the influence of human activities in the past in Central Chile, we compare different historical periods (e.g., Spanish colonization, beginnings of the Republic of Chile, great acceleration -1950 onwards-) and their impact on the contributions of sediments and nutrients to four lakes. These lakes are Laguna Matanzas, Laguna Aculeo, Lago Vichuquén and Lago Lanalhue, all of them with human influences during the last centuries. The main result shows a high organic matter content and input of Nitrogen with the increased of forest plantations and intensification of agriculture. The knowledge about lake-watershed dynamics is key to unravelling and mitigating any negative effects that human-driven processes have on terrestrial and aquatic ecosystems and improve our understanding in the context of Global Change.

Attempt to reconcile discrepant luminescence and radiocarbon ages of trans-Himalayan (Ladakh) palaeo-lake sediments

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Even after numerous attempts, it is still difficult to establish a reliable chronology and understand the dynamics of western disturbances (a non-monsoonal precipitation pattern), a major source of winter moisture in the Trans-Himalayan region. Radiocarbon and luminescence dating methods have their own sets of a specific issues that must be resolved for faithful past climate reconstruction. To highlight the discrepancy, published luminescence ages of sediment from Spituk Lake at a height of ~ 20 m from the basement that were measured at different times, are 72 ± 2 ka, 58 ± 3 ka, and 30.2 ± 1.8 ka whereas the radiocarbon age is 3.3 ± 0.1 ka.

Overestimation of luminescence ages can be due to 1) poor sensitivity of quartz to ionizing radiation ($cts.Gy^{-1}.mg^{-1}$) and 2) incomplete resetting of luminescence prior to the deposition. Thus, to overcome the lower signal-noise ratio, researchers use larger aliquots and ended up having more poorly bleached grains in the aliquots that overestimated the ages. From this premise, we deduced a hypothesis - the luminescence ages based on smaller sized aliquots might correspond to the depositional event. So, we extracted pure quartz grains of size 90 -150 μm of one sample from Saspol Lake (Khalsi) and that was dated using big (BA: ~ 60000 grains), medium (MA: ~ 2300 grains) and small (SA: ~ 300 grains) aliquots. The estimated luminescence ages are 20.1 ± 0.8 ka (BA), 18.0± 1.0 ka (MA) and 5.5±0.4 ka (SA) whereas the radiocarbon age of the nearby sample is 11 ka. This observation supports our hypothesis. Radiocarbon ages from this region also have issues such as 1) hard water effect and 2) fresh water reservoir age.

To reconcile both the luminescence and radiocarbon ages with adequate explanatory mechanism(s), we collected samples for both dating methods from the same strata of two palaeo-lakes, Spituk (9 samples) and Saspol (5) from Ladakh. Radiocarbon ages are apparently older (18 ± 0.1 ka) and stratigraphically inconsistent. Luminescence ages are being estimated using bigger and smaller aliquots of quartz grains, We would like to elucidate the results in the conference for better understanding.

Towards the timing of the infill of glacially overdeepened basins using single grain pIRIR feldspar luminescence dating.

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The multinational pan-alpine research project ICDP - DOVE (International Continental Scientific Drilling Program - Drilling Overdeepened Alpine Valleys) currently investigates overdeepened structures on the northern side of the Alps. The infill of these overdeepened basins potentially provides a geo-archive for the reconstruction of depositional processes and paleoenvironmental conditions in the Alpine realm. Deciphering this valuable information requires a numerical chronology, which in the ICDP - DOVE project is going to be achieved by implementing a combination of different dating methods, including luminescence dating approaches. The expected age range covers time beyond the last glacial cycle. As the age range of quartz does not allow the calculation of reliable ages in this time frame. Therefore, signals from potassium-rich feldspar are used. The expected incomplete bleaching in the depositional environment (glacial waterlain deposits) is being investigated and discussed. As shown by previous studies and initial measurements, multigrain aliquots very likely represent age overestimation, often even limited by signal saturation. To circumvent this issue single grain (SG) measurements of potassium-rich feldspar using the pIRIR225 (post infrared, infrared stimulated luminescence @ 225°C) single aliquot regenerative (SAR) dose protocol is applied. We present first results from initial samples of complementary glacial overdeepenings with a focus on applicability of the pIRIR SG dating approach, reliability of the detection of incomplete bleaching, and establishing a maximum dose range for the different overdeepened basin catchment areas. Furthermore, preliminary IR and pIRIR ages are presented.

When were the Nazca Lines (Peru) created? New data from rock surface burial dating

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The Nazca Lines at the south coast of Peru are among the world's most enigmatic geoglyphs and a UNESCO world heritage site. Drawn on the desert by the Paracas and Nazca cultures (800 BC–AD 700), they comprise large (up to a few km) geometric structures such as lines, trapezoids and spirals, as well as figurative depictions (spiders, birds). They were created by removing the dark, patinated stone layer from the desert pavement, exposing the lighter silt layer beneath and accumulating heaps of stones on their edges. Beside their actual purpose, there are still many open questions about their chronology and when they were made, such as the temporal relationship between geometric and figurative depictions, and why and when some geoglyphs were superimposed onto previous ones.

To address these questions, we took 57 rock samples for luminescence burial dating from a spiral, superimposed trapezoids and one zoomorphic design. Preferentially felsic samples devoid of patina were chosen such that they were most likely re-located by the Paracas and Nazca people during geoglyph construction. Drill cores were obtained from the lower (shielded) surfaces of these stones and luminescence-depth profiles measured from cut slices. A plateau of normalized natural luminescence intensity within the first few mm below the surface served as an indicator of an archeological dose corresponding to the burial of rock surfaces during construction. Additionally, we sampled the silt layer beneath the desert pavement to assess the temporal scales involved in the formation of this geoarchive.

Results indicate the general datability of the geoglyphs and that granite is the most suitable lithology. This contribution presents new data on unravelling the temporal relationship of superimposed structures and the age of a figurine drawing. We outline the problems encountered in the dating process and discuss the robustness of the chronometric results. Further geochronological analyses show that the desert pavement exists since at least MIS 4-3, indicating that this geomorphic form has endured several major climatic fluctuations.

Extension of quartz luminescence chronology using the multiple aliquot regeneration technique in the Drzovice loess profile, Czech Republic

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The extension of quartz luminescence chronologies is a key issue when investigating dust accumulation rates in the last glacial cycle since by using traditional single aliquot regeneration (SAR) protocols the upper limit of dating is usually at around 50-70 ka, and in many applications, MIS 3 and MIS 4 accumulation rates can hardly be investigated this way. Although other, feldspar-based protocols (e.g. post-IR IRSL) are available for these periods, but uncertainties related to these, caused mainly by residual doses and anomalous fading, are considerably higher than in the case of quartz.

The multiple aliquot regenerative dose (MAR) protocol is one of the potential solutions to extend the quartz age range, as based on saturation tests and other luminescence characteristics, it might be applied up to 100 ka. However, we have limited data on the reliability of MAR-derived luminescence ages in comparison to other protocols.

In our study, four samples were selected from the Drzovice loess profile, covering the LGP and the MIS 5 paleosol. First, the fine-grain quartz fraction of samples was subjected to SAR and, MAR measurements. Then, to validate quartz MAR ages $pIR_{50}IR_{290}$ measurements were made on the polymineral fraction. As MAR ages in two cases exceeded pIRIR-derived ages, we determined pIRIR fading rates and calculated α-efficiency values for both fractions. We found that quartz MAR ages correlate well with fading-corrected pIRIR ages, and have a significantly lower uncertainty. We propose therefore to apply the quartz MAR protocol when establishing age models for LGP Moravian loess deposits.

Age and genesis of diamictons in the Mologa-Sheksna Lowland and adjacent areas

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The Mologa-Sheksna lowland (MShL) is located in the north-west of the East European Plain. In the Late Valdai (Late Weichselian) the margin of the Scandinavian Ice Sheet (SIS) reached the MShL, however the limits of the maximum ice sheet expansion are still debatable. According to Garkusha (1965), the margin passed south of the Sheksna river and the most part of the MShL was occupied by the ice lobe. Pursuant to Gey (1990), the margin ran north of the MShL along the Belozersk-Kirillov and Tikhvin end moraine ridges.

We investigated five key sections with diamictons north and west of the Rybinsk reservoir, to reveal whether the SIS reached its current basin. The genesis of diamictons found at Abakanovo (N59°15’29.4”, E37°40’51.4”) and Shenskoye (N58°30’24.4”, E37°06’42.3”) is debatable and requires further studies. At Abakanovo the diamicton is covered by loessoid with quartz OSL age *ca.* 20 ka and underlain by fluvioglacial sand and gravel with quartz OSL ages 155–118 ka (K-rich feldsparp $IRIR_{290}$ ages 299–212 ka). At Shenskoye the diamicton is underlain by lacustrine and alluvial sediments with quartz OSL ages 73–62 ka.

In sections Gorinskoye (N58°24’09”, E37°32’34”), Timonino (N58°15’02”, E37°53’28”) and Suscheva (N58°15’23”, E37°52’06”) the diamictons can be steadily interpreted as subglacial tills. In all three sections the tills are overlain by loessoids or alluvial sand with quartz OSL ages 22–15 ka. At Gorinskoye the till is underlain by deformed fluvioglacial sand and gravel with quartz OSL ages 112–72 ka (K-rich feldspar $pIRIR_{290}$ ages 227–204 ka). Orientation of a huge overfold near the till bottom suggests that the glacier moved from north-east to south-west. At Timonino and Suscheva the tills are underlain by deformed sand and gravel with quartz OSL ages 163–103 ka (K-rich feldspar $pIRIR_{290}$ ages 447–324 ka). According to the orientation of folds and faults in the glacitectonites, the glacier moved from north-west to south-east at both sites. We consider quartz dates obtained for the submorainic deposits as minimum ages due to saturation effect at high equivalent doses (>150 Gy) and K-rich feldspar dates as maximum ages because of possible incomplete bleaching.

The potential of violet stimulated luminescence (VSL) to extend the chronology at the Fantasma Site in Atapuerca, Burgos, Spain

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Over the past decades, optically stimulated luminescence (OSL) dating has become a key tool in the study of Quaternary sedimentary records. It can provide absolute ages ranging from decades to several hundred ka using standard procedures. Despite the power of the technique, demand for extending the age range has increased significantly in the past years, resulting in a large concentration of effort in this respect. Violet stimulated luminescence (VSL) has been proposed as one approach for meeting this objective. It has been shown that VSL yields a luminescence response that saturates at higher doses than the conventional blue-OSL signal from quartz. This study focuses on the application of VSL to sedimentary quartz samples from Fantasma Site in the UNESCO World Heritage archaeological sites of Atapuerca in Burgos, Spain.

Five samples from a 10 m-thick cave infill have been the target of this study. The conventional blue-OSL response increases at increasing depths, as expected, but the signal of the deeper-most sample is near the saturation limit of the signal, compromising the reliability of the age estimation. This also limits the possibility of dating the sedimentary units below (not included in the present study) using standard procedures of luminescence dating. VSL from the quartz extracts of these samples show a reproducible response which saturates at higher doses than the blue-OSL signal providing therefore, the possibility of reaching older ages. An extensive experimental study using VSL, including analyses on the effect of the stimulation temperature, the normalizing dose or the bleaching of the signal among other tests have been carried out to determine the most suitable measurement protocols and to confirm the reliability of the method to recover a given dose. Based on the results, equivalent doses using VSL up to 500 Gy can be recovered, in contrast to a maximum dose around 300 Gy that can be reached with conventional blue-OSL.

This study shows the potential of VSL to extend the age range beyond the limits of conventional luminescence dating in this site.

Environmental dose rate calculation for deep ocean sediments: Measure, model or guess?

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Luminescence dating of deep ocean sediments is complicated by disequilibrium in the ^{238}U and ^{235}U decay series, which cause the environmental dose rate to vary as the sediment ages. Production of insoluble isotopes (^{230}Th and ^{231}Pa) in the water column overlying the sample site causes the incorporation of these isotopes in excess. This excess activity decays over time, leading to a progressive decrease in dose rate due to excess isotopes. In anoxic sediments, uranium can be incorporated into sediment without its decay products, leading to an increase in dose rate as the sediment ages and this "authigenic" uranium tends towards secular equilibrium. Direct measurement of excess and authigenic isotopes is possible via mass spectrometry, but this is time-consuming. Furthermore, accurate differentiation of authigenic and minerogenic uranium is challenging. However, while direct measurement of disequilibrium is usually preferable, it may be possible to derive good approximations of the excess and authigenic isotope concentrations via modelling. The primary controls on excess isotope concentrations are water depth (production) and sedimentation rate (dilution). Where these quantities are known, burial activities of excess ^{230}Th and ^{231}Pa may be estimated. Authigenic uranium concentration may be estimated as total uranium minus minerogenic uranium. The latter quantity can be calculated assuming a fixed abundance/activity ratio of minerogenic U/^{232}Th, since the latter can be assumed to be invariably minerogenic. This poster presents methods for calculating dose rates for deep ocean sediments, using either direct measurements or modelling of excess and authigenic contributions, and identifies situations where the latter approach may be inappropriate.

Environmental DNA and geochemical proxies track Dorset/Thule transition on Somerset Island in Arctic Canada, part II

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Favourable sedimentary ancient DNA (sedaDNA) preservation in archaeological freshwater ponds on Somerset Island in Arctic Canada has allowed for not only a rich taxonomic profiling of flora and fauna through the Dorset/Thule transition as discussed previously by Kissinger and colleagues in part I, but the richness and abundance of faunal sedaDNA have also allowed for species-specific phylogenetic analyses. Here in part II, we continue the multi-proxy report from Kissinger et al., presenting preliminary results on wolf/dog and bowhead whale phylogenies using mitochondrial genomes reassembled from the same freshwater pond sediments. The presence of what appears to be Greenlandic dog mitochondrial genomes supports early archaeological evidence of sled dog use in the area. Thereafter, we discuss coeval changes in microbial community composition as observed with sedaDNA which appear to be associated with subsistence and ecological transitions at the site. We conclude with a discussion of how ancient environmental DNA and complementary proxies have helped to redefine the information potential of sediments by providing novel insights into hunter-forager palaeoecologies in the high arctic.

The first mitogenome records of European woolly rhinoceroses (Coelodonta antiquitatis), isolated from coprolites of cave hyenas (Crocuta crocuta spelea)

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The woolly rhinoceros (*Coelodonta antiquitatis*) is an iconic species of the Pleistocene megafauna, which was abundant in Europe in the Pleistocene until its demise beginning approximately 10,000 years ago. Despite the wide distribution of this species throughout northern Eurasia and numerous findings of remains in western Europe, comparably little genomic information is available, and all currently published mitogenomic data of woolly rhinoceroses stem from Siberian findings, whereas DNA data from European populations is to date limited to short fragments. Two coprolites of cave hyenas (*Crocuta crocuta spelea*) were recovered from late Middle Palaeolithic horizons in two caves in southwest Germany (Bockstein-Loch [BS] and Hohlenstein-Stadel [HS]). The BS specimen was retrieved during excavations in 1934, and the HS coprolite was recovered during excavations between 2008 and 2013. We extracted DNA from approximately 100 mg of each sample, and mammalian DNA was enriched through targeted hybridization capture. After high-throughput sequencing, we assembled the first two (albeit incomplete) mitogenomes of European woolly rhinoceros, in addition to cave hyena mitogenomes. The assembled mitogenomes produced a coverage of 81% (*C. antiquitatis*) and 59% (*C. crocuta*) from one coprolite (BS), and of 27% for both species from the other (HS). The recovered DNA was highly degraded and showed considerable damage, which complicated molecular dating and phylogeographic analyses with respect to divergence time of the European and Siberian woolly rhinoceros populations. However, our phylogenies, which include all previously published mitogenomes of woolly rhinoceroses, suggest a plausible pattern of divergence of the European and Siberian woolly rhinoceros clades. In addition, our cave hyena phylogenies placed our European isolates in an ancient European clade which has diverged earlier from the three modern African spotted hyena clades than two other ancient European ones. Further genomic insights could be gained through increased sequencing depth and using larger sample mass for DNA extraction. Our results provide, for the first time, genomic information on European woolly rhinoceroses and will thus help further resolve the phylogeography of ancient Rhinocerotidae.

How the exceptional preservation at Schöningen opens new perspectives on hominin lifeways during the Middle Pleistocene of Northern Europe

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Since the 1990s, systematic excavations by the Heritage Office of the State of Lower Saxony and the University of Tübingen in Schöningen have exposed several thousand square meters of thick deposits from the Reinsdorf Intergracial Complex dating to roughly 300,000 years ago. These waterlogged lakeside sediments on the edge of an open-cast lignite mine provide an ideal archive for reconstructing the past environmental conditions, ecological dynamics and hominin behavior during the late Lower Paleolithic. This paper presents a view of the rich geological, botanical, faunal and archeological records from Schöningen and focuses on how these sources of information allow a uniquely complete reconstruction of the ecosystem in the surroundings of this former lake basin. We then use the exceptional archaeological record, including numerous wooden artifacts, to reconstruct what is likely the most detailed and compelling reconstruction of hominin lifeways and technological responses to changing environmental conditions from the Middle Pleistocene. The setting in Schöningen allows us to consider how our views or the past are strongly shaped and often limited by the taphonomy and site formation processes.

Late Glacial paleoseismicity in Carinthia (Eastern European Alps): lake sediment studies of strong seismic shaking events and a coseismic surface rupture.

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Numerical models and paleoseismic records often suggest enhanced seismic activity during several millennia after regional deglaciation. To better understand how stress field changes related to deglaciation and postglacial isostatic rebound may govern earthquake occurrence, additional strategically-located paleoseismic records are needed.

Glacigenic lakes Wörthersee and Klopeinersee are located in the Eastern European Alps at the eastern edge of LGM ice extent. The tectonic regime of the region is governed by several dextral strike-slip fault zones, along which large historical earthquakes took place in AD1690 (M_w~6.5) and AD1348 (M_w~7). We investigated the sedimentary infill of the lakes for traces of past seismic shaking in the form of multiple mass-transport deposits (MTDs) and turbidites. We combined reflection seismic profiles (pinger and sparker) with long sediment cores, which were analyzed by X-CT scanning, Geotek MSCL, Itrax XRF scanning and grain-size measurements. Bayesian age-depth models were constructed based on ^{14}C dating of terrestrial macroremains.

We focused on the Late Glacial part of the sedimentary sequences characterized by clastic input in proglacial and/or periglacial environments. In Klopeinersee, this covers the period ~18 to ~16 cal ka BP in which we identified 6 event horizons, 5 of which involve multiple MTDs. In Wörthersee, we identified 3 event horizons with multiple MTDs. The latest event occurred at ~14.1 cal ka BP, generated large landslides in all sub-basins and involved a large volume of 29×10^6 m^3. In the western basin of Wörthersee, these mass-transport deposits directly overly a locally disrupted seismic stratigraphy that can be traced for ca. 4 km along the basin axis. This “disrupted area” typically shows chaotic reflections bordered by reflection hyperbolae. It forms basin-like depressions that are 1-2 m deeper than the intact sediment units. We interpret this as a SW-NE oriented surface rupture related to the major earthquake at ~14.1 cal ka BP. The small depressions could represent sag ponds related to transtensional deformation along a dextral fault. Interestingly, these observations coincide with a non-studied “assumed” fault on the local geological map, the hazard potential of which has not been considered yet.

Preliminary neotectonic assessment of the central segment of the Acazoque fault in the southern Andean Plateau (Puna), north-western Argentina

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The Acazoque fault is a NNE-striking crustal-scale structure that can be traced for 200 km in the southern Andean Plateau of the Central Andes in Argentina; the fault can be divided into a southern, central and northern segment. The southern segment is 53 km long, oriented N23° and defines the eastern border of the southernmost part of the Salar de Antofalla basin. The 66-km-long, N28°oriented northern segment, controls the western limit of the Salar del Hombre Muerto and juxtaposes Ordovician basement rocks over Cenozoic sequences. The N48° striking central segment is approximately 80 km long and constitutes the structural link between the northern and southern segments.

Analysis of a TanDEM-X digital elevation model combined with high-resolution satellite images (Google Earth, Bing Maps), and field inspection allowed the identification of a series of morphostructures interpreted to be related to Quaternary dextral strike-slip deformation along the central segment, two of which are described here.

First, the Salitral Potrero Diaz (25°28'S, 67°20'W) is a 2-km-wide rhomboidal salt marsh located on a releasing bend of the central segment of the Acazoque fault. A N52° striking, 1.5-km-long fault scarp with an apparent normal sense of motion, has ruptured the northwestern sector of the Salitral, uplifting its northwestern block. Immediately to the southwest, two subparallel scarps affect an adjacent alluvial braidplain, defining a 2-km-long, 300-m-wide graben. Kinematic data on Pliocene lavas cropping out along the southwestern margin of the basin supports the notion of a transtensive regime with a dextral strike-slip component.

Second, about 13 km southwest of the Salitral Potrero Díaz, two 2-km-long, N20° oriented, subparallel hills have developed in a restraining bend of the central segment of the Acazoque fault. While the western hill is 100 m high, the eastern one is only 35 m, suggesting eastward migration of deformation. This interpretation is further corroborated by a subparallel 1-m-high fault scarp 500 m east of the eastern hill affecting the most recent alluvial braidplain sediments.

This sector of the southern Puna is characterized by Quaternary transtensional/transpressional deformation, superseding regional shortening in the orogen interior since the Late Pliocene.

Characterizing the seismogenic potential of the Hengchun offshore structure, southern Taiwan, using uplifted coral colony records

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Offshore southernmost Taiwan, a Hengchun offshore structure has been proposed by some previous studies to be located to the west of the Hengchun Peninsula. This structure would be a potentially seismogenic fault, and may be responsible for the coastal uplift of the western peninsula. However, the presence of this structure is under debate, and some argued that the area may be uplifting aseismically by mud diapirism, because no record of paleo-earthquakes related to the structure was identified. We utilized fossil coral colonies along the western Hengchun Peninsula as paleo-sea-level indicators to identify paleo-earthquakes probably produced by this structure over the past 2.5 kyr. Uplifted Porites coral colonies were found at multiple sites along the coast, and can be separated into six groups based on their elevations and ages. At one site, corals in the same age group have similar elevations, and corals found at different sites along the coast can all be correlated into the six groups. These observations suggest that these coral colonies likely recorded co-seismic uplifts of six paleo-earthquake events of the proposed Hengchun offshore structure. Our results suggest that the Hengchun offshore structure is capable of producing substantial earthquakes and poses significant regional seismic hazard potentials in the future, whereas mud diapirism is not the primary structural mechanism in the area.

Soft-sediment deformation structures as natural seismographs: What are the key controlling factors?

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Soft-sediment deformation structures (SSDS) are commonly used as paleoseismic indicators in lacustrine sedimentary sequences. Recent studies suggest that SSDS can be used to reconstruct the shaking strength of past earthquakes and not only recurrence rates. The use of SSDS from different lacustrine settings for quantification of seismic shaking strength requires a thorough understanding of the modulating effect of i) lithology, ii) slope morphology, and iii) sedimentation rates.

Here we evaluate the influence of lithology and sedimentation rate by linking sedimentary basin sequences from ten different lakes from all over the world to strong historical earthquakes in each region. The lakes have different lithologies and are all located in active seismotectonic regions with different types of seismogenic sources (i.e. interplate, intraplate and intraslab). We evaluate if time horizons of strong seismic shaking within the sedimentary sequence are marked by positive or negative evidence of deformation (i.e. earthquake-triggered SSDS present or not). We assess lithological differences using high-resolution XRF-scanning chemical element profiles and density differences using radiodensity measurements (i.e. based on X-ray computed tomography scans) and gamma density. Our data suggests that deformation in basin sequences only occurs within sediments in a certain density range. To evaluate the effect of slope morphology and clastic deposits intercalated within background sediment, we investigated 25 earthquake-related SSDS within 17 sediment cores taken on different slope angles from lake Riñihue, Chile. We find that higher slope angles lead to thicker SSDS, but also that the burial depth of clastic deposits during seismic shaking modulates SSDS thickness as the first stratigraphically available clastic deposit often functions as basal shear surface. In addition, the thickness of the deforming sequence modulates the intensity of deformation, as earthquake-induced shear energy is more concentrated within thinner deforming sequences, thereby leading to stronger deformation.

Our study aims to advance paleoseismology based on SSDS records and to push its potential to reconstruct shaking strength of past events.

Imaging active submarine faults using ultra-high resolution methodologies: Preliminary results of the STRENGTH 2023 cruise in the Alboran sea

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The fault seismic potential is usually characterized based on active tectonics and paleoseismology analyses, which provides information such as fault geometry, slip rate, recurrence period, displacement per event and elapsed time since the last event. These are parameters commonly used in seismic hazard assessment. In addition, these type of analysis are of special importance in areas of relatively slow tectonic deformation with faults capable to generate moderate to large-magnitude earthquakes (Mw > 6), with long recurrence intervals (10^3 to 10^4 years), such as those in the Alboran Sea (westernmost Mediterranean). During the last decade, we have been able to map the main fault systems in the Alboran Sea, such as the Carboneras, the Yusuf, the Al-Idrissi and the Alboran Ridge fault systems. The next step in the characterization of these submarine active faults is to acquire ultra-high resolution datasets using the most advanced technologies in marine geosciences, such as Autonomous Underwater Vehicles (AUV) and Remotely Operated Vehicles (ROV). During the STRENGTH cruise (March-April 2023), we have used these type of vehicles to acquire bathymetric and backscatter datasets with 1 meter pixel resolution, seismic profiles with centimeter vertical resolution and video cameras to image interesting areas along the different identified active fault systems in the Alboran Sea. These new dataset will allow a better characterization of the seismogenic potential of these fault and, thus, improve our knowledge about seismic and tsunami hazards in the surrounding coastal areas.

Looking at the opportunities for tectonic basin sedimentation record in Java Island

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Java Island is one of the world's most populated islands and is Indonesia's central strategic Island. As part of the pacific rim region, this Island faces the threat of earthquake disaster. Understanding paleo-seismology is an essential step in developing an effective mitigation system. However, unlike Sumatera, due to characteristics of the Java tectonic setting, the interval between the destructive earthquake events becomes longer. Even though some earthquakes have been noticed in the historical record, most ancient destructive earthquakes become untraceable. Volcanism, bioturbation, weathering, and anthropogenic factor degrade the tracks from the geological outcrops. The sediment records from tectonic lakes would be a beneficial source of information. However, the research on paleo-seismology using tectonic lake sediment in Indonesia needs to be improved. Especially on Java Island, exploring information from the existing natural tectonic lakes is more complicated. Along active faults, there were several basins, which were recognized as lakes, and the wetland became dried and transformed into farms or settlements. This paper will reveal the trace of ancient fault activities preserved in some basins with morphological features suggested as tectonic basins. This paper reviews the published literature and proposes a simple interpretation of the morphology of the basin using Google Earth satellite images and the Digital Elevation model to increase the level of analysis. The focus area is the sag ponds located along two active faults in Java Island, Lembang fault, West Java, and Kalibening- Wanayasa Banjarnegara, Central Java. The sag ponds along the Lembang fault area provide the sequence that shows signs of major destructive events and have been the research targets by paleo-seismology experts. On the other hand, the Kalibening basin consists of quaternary alluvium sediment hypothetically identified as the lakes formed in the releasing bend area of the Kalibening-Wanayasa active fault. This paper's result will show the usefulness of the sediment sequences as records of paleo-seismology on Java Island.

Down to earth: on the origin and the seismogenic potential of the major transverse lineaments crossing the Italian landmass

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The last few decades produced a vast body of knowledge concerning Italy's seismotectonics, spurred by the pivotal 23 November 1980, Mw 6.9 Irpinia earthquake. Indeed, normal faulting was (and is) paramount along the backbone of the Apennines, and dominates the landscape, with contraction having built up the core of the edifice and now prevailing along sectors of the leading edge.

Yet, a set of oblique regional features is somewhat masked within the tectonic edifice, bearing an unclear seismogenic role. These long-ranging and long-studied features have been hypothesized to accommodate the geodynamic evolution of the central Mediterranean and the tectonic transport leading to the Apennines' build-up, or have been described as lineaments.

Earthquakes affecting the Italian landmass occur primarily along the axis of the Apennines, mimicking their poly-arcuate shape associated with an essentially cylindrical tectonic style, with kinematics encompassing all faulting mechanisms. However, a number of strong historical and instrumental earthquakes appear to elude this general interpretation; some of them have been associated with sources that are deeper-seated or farther into the foreland.

Based on their location with respect to geodynamic province, focal mechanisms, and structural position, we highlight three primary categories of such events:

- those occurring along major inherited Mesozoic, poly-phased structures, affecting the Adriatic and Maghrebian foreland. These faults, likely resulting from the Tethyan break-up, have caused some of the most destructive events of the Italian record;
- those resulting from differential motions between adjacent panels of retreating subduction. Such mechanism may be responsible for some of the long-discussed lineaments identified across the northern Apennines;
- those thought to occur along segments of the hard edge accommodating the differential motion between forwarding, outer fronts of the southern Apennines and the retreating slab beneath the Calabrian arc (STEP).

We aim at breaking these spatially and tectonically diverse transverse features down into a coherent hierarchy, to contribute to deciphering seismogenic processes affecting the Italian landmass. Our goal is to create an interpretive tool of active deformation and help recasting past, elusive earthquakes, to infer whether specific segments of inherited transverse structures may be the causative source(s) of future damaging earthquakes.

What if a strong earthquake hits again Spain? Risk Estimation of historical earthquakes in Present times

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Few significant earthquakes affected mainland Spain, during the 20th and 21st centuries. Most of them of moderate magnitude (c. 5.0 Mw) and intensity VII to VIII ESI-07/EMS-98 as is the case of the 1956 Albolote, 1964 Galera, 1992 Mula and 2011 Lorca seismic events, the last causing a total of 11 casualties. From 1971 to 2018 the compensations due to earthquake damage rise up to 536.5 M€ (updated) from which 517.6 corresponds the Lorca event.
However, the 19th century records at least 5 strong events of magnitude 6 to 7 Mw with intensities ranging from VIII to X ESI-07/EMS-98. This is the case of the 1829 Torrevieja (IX-X) and the 1884 Arenas del Rey (IX-X) events which caused important casualties (389 and 900 respectively) and quite significant economic losses. Ground motion scenarios (ShakeMaps) of these two historical events compiled from ESI-07/EMS-98 macroseismic data allow the further implementation of the USGS PAGER routines (Prompt Assessment of Global Earthquakes for Response) to explore the extent of damage and economic losses for strong historical earthquakes in Spain. Combined with actual databases of the population in each Intensity zone PAGER estimates Seismic Risk (economic losses and fatalities) for a precise event. Loss models are empirically based and offer country specific results. The estimated losses define a color-coded alert, which determines the suggested levels of response: from no response needed (green) to international response (red).
Obtained PAGER loss scenarios from the Torrevieja and Arenas del Rey applied to present day population databases show alarming results as they incorporate the notable increase in vulnerability and exposure related to urban expansion experienced since the last quarter of the 20th century. In all explored scenarios the obtained response levels are red (International Response needed) with very important economic loss and prominent number of fatalities. Estimated losses exponentially rise when risk scenarios incorporate the increase of population during touristic seasons. The magnitude of the obtained loss indicates that today Spain is not prepared for such kind of strong events, damage scenarios are not even contemplated in official regulations and mapping for seismic risk in Spain. Funded by MINCIN-FEDER 2021-123510OB-I00.

Cave paleoseismology insights for Costa Rica: Cases of studies and future applications into the LATAM region

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The use of caves in paleoseismology studies had positive research results in various cases of studies worldwide such as in Italy, France, Cuba, Bulgaria, Switzerland, and Slovakia. Caves are favorable zones to preserve the fault's deformations in a three-dimensional space that can give valuable data for the paleoseismology and structural characterization of the fault rupture. In tropical regions, the density of vegetation, and soil is sometimes difficult registration of continuous and reliable structural data. In caves near fault systems, you can find various of structural-active tectonic data, e.g., tilts chambers, broken/tilts speleothems, deformed sediments, and stretching lineation. Cave patterns also gave a lot of data for structural lineation and fracture characterization of the zone. Detail recent studies along the 3 principal karstic zones in Costa Rica, had shown different speleotectonic characteristics to be studied. Venado of San Carlos karstic zone is emplaced into an active transtensive system, the caves in the zone show deflected passages, basculated speleothems, strain lineations, and secondary mineralogy. The principal cave "Gabinarraca" follow the principal fault trace heading. This zone has been impacted due to local earthquakes e.g., 1970s Tilaran Earthquake (6,5 Ms) and Cañas Earthquake (7,7 Ms). Barra Honda, located in Nicoya, show different basculated speleothems and flooded zones, broken and deflected chambers that can be associated due to the Nicoya subduction earthquakes e.g., 1950 (~7.7 Mw), 1990 (7,3 Mw), and 2012 (7,6 Mw). South Costa Rica Karstic zone had different varieties of cave-tectonics characteristics such as deflected chambers, broken and basculate speleothems, and different vertical displacements along fractures. This zone has also been influenced by subduction earthquakes 1904, 1941 and 1983 from magnitudes above 7 Mw. This work brings out some of the new cave tectonics findings along the different Costa Rica karstic zones, that have been or can be studied as complementary data for fault characterization, paleoseismology, and earthquake cycle using different technology as LIDAR, photogrammetry, and structural data. These different findings and applications of tropical cave tectonic studies can be also be applied along the LATAM region as a complement to enforce the fault characterization, risk assessment, and seismic zoning studies.

Tectonic geomorphology and transient landscape response of the Sparta Fault (Greece)

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The Sparta Fault is a major active normal fault in southern Greece, it is 64 km long and forms the western margin of the Sparta basin. The last known rupture of the fault was in 464 B.C. during a ~7.2 M_w earthquake that severely damaged the antique city of Sparti and caused ~20,000 deaths. This rupture is hypothesised to have occurred along the southern section of the fault owing to a well-preserved post-glacial fault scarp with > 10 m accumulated throw over 15±3 ka. In contrast, along the northern segment of the fault there limited to no records of post-glacial fault scarps, leading some researchers to conclude that the northern segment is less active. We investigate the Quaternary activity of the entire structure using a combination of tectonic and fluvial geomorphology to reveal uplift effects on river channels and the distribution of post-glacial surfaces. The river profiles of rivers flowing across the fault were extracted from the ALOS World AW3D30-DEM to determine Quaternary fault activity, and the height of the post-glacial fault scarp was investigated through fieldwork and DEM analysis, with dip/dip direction and slip vectors measured along the fault. The longitudinal profiles of rivers contain slope-break knickpoints along the entire length of the fault, with the normalised steepness index downstream of the knickpoint showing a normal but southerly skewed distribution, thus indicating higher fault activity in the southern section. From fieldwork on the post-glacial scarp, the dip varies along the length of the fault, with the central section dipping more shallowly (~45°) than the northern and southern sections (~60°). Finally, we report a new post-glacial fault profile recording 8.45±1.69 m of throw, corresponding to a slip rate of 0.56±0.16 mm/yr on the northern segment of the fault. In comparison, published slip rates fall in the range 0.45 to 1.07 mm/yr. Therefore, our data show that it is likely that the entire length of the Sparta Fault should be considered as an active fault. In particular, the northern segment which was previously stated as inactive is here shown to be active during the Quaternary.

The AD 1909 Benavente Earthquake: Seismic source modelling from the analysis of ESI-07 environmental data

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This work presents a macroseismic analysis of the AD 1909 Benavente Earthquake by means of the combination of intensity data derived from the EMS-98 scale and the ESI-07 scale (Environmental damage). The Benavente earthquake happened on April 25, 1909 with a maximum intensity of X EMS-98 in the vicinity of the towns of Benavente and Lisbon, with an assigned magnitude of 6.0 Mw, affected all of Portugal and was felt in many towns in western Spain, covering an area of more than 20,000 km^2. More than 150 records of EMS-98 intensity and about 70 records of secondary earthquake environmental effects (EEEs) have been used to define intensities, focused on the vicinity of the mouth of the Tagus River in Lisbon (ground cracks, liquefaction processes, anomalous waves, hydrogeological anomalies, etc.). A modeling of the seismic source has been performed from ShakesMaps using the intensity data (EEE and EMS-98) inventoried for this earthquake. With this analysis we have tested the location and extent of the possible seismic sources defined for this event. Research funded by the MINCIN-FEDER 2021-123510OB-I00 (QTETC-SPAIN-USAL).

Elemental Composition (XRF) of Modern Tidal Wetland Sediments and their Potential for Reconstructing Land-level Change along Cascadia Coastlines

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Understanding the relationship between modern salt marsh sediments and tidal inundation along a coastline is critical for reconstructing past sea- and land- level change. Established methods for reconstructing such changes predominantly rely on microfossil assemblages which zonate vertically within a marsh as a result of exposure to tidal inundation. In this study, we investigate the utility of elemental compositions on bulk surface sediments (upper 1 cm), obtained through x-ray fluorescence (XRF), as an indicator of tidal elevation from two tidal wetlands along the Cascadia subduction zone.

A total of 108 samples from eight transects were collected from Willapa Bay, WA, USA (5 transects; 75 samples) and Port Alberni, BC, Canada (3 transects; 33 samples). At both locations, transects span the full marsh gradient and have been shown to zonate with respect to the tidal frame using diatoms (Willapa Bay) and foraminifera (Port Alberni). To test whether elemental compositions will also zonate with respect to tidal inundation, we analyzed each surface sample using an Itrax-XRF Core Scanner. Principle Component Analysis (PCA) on preliminary results from Willapa Bay indicate that elemental composition can distinguish between the high marsh, low marsh/tidal flat, and the subtidal zones. Results show that bromine, silicon, aluminum, titanium, and the incoherent/coherent scattering ratio are dominant vectors controlling the differentiation between the marsh subenvironments. At Willapa Bay, the elemental composition of the same set of surface samples revealed similar grouping compared to a previously published modern training set showing that diatoms in the region respond to tidal inundation. The excellent agreement between the two datasets highlights the applicability of elemental geochemistry, a rapid and high-resolution technique, as a proxy for developing critical training sets for sea- and land-level reconstructions along Cascadia coastlines.

Morphotectonic evaluation and Paleoearthquakes studies of the Himalayan frontal belt bounded by the Main Boundary Thrust (MBT) and Himalayan Frontal Thrust (HFT), Kumaun Central Himalaya

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The Himalayan frontal belt, bounded by the Main Boundary Thrust (MBT) and Himalayan Frontal Thrust (HFT), is one of the most active mountain belt in the world. It is essential to understand the landscape evolution in the foothill zone of the Himalaya, which has been significantly influenced by the ongoing deformation and associated earthquake events. In the Haldwani-Tankapur region of Kumaun central Himalaya, fault-related-fold growth generally formed various geomorphic markers like the diversion of the river from its original course and formation of wind gaps, formation of river terraces, and such geomorphic markers can be utilized in the reconstruction of deformational events in tectonically active regions. The terraces along the major rivers like Gaula, Sarda, and Nandhaur river crossing MBT and HFT provide good constraints on the incision/uplift rates, where rivers are forced to cut down into the rising anticlines of the Siwaliks rocks resulting in abandoned paired/unpaired strath terraces. We have mapped the geomorphic markers of the region with the help of high resolution Cartosat-1 (2.5 m spatial resolution), prepared a detailed tectono-geomorphic map of the region, conducted detailed field investigations, and collected samples for the OSL dating. The ages from the youngest strath terraces of the Gaula river along MBT suggest the abonnement of the terrace between 1775-1871 AD, and the youngest terraces of the Nandhaur river and Haldikhal Gad along the HFT suggest the abonnement between 1282-1623 AD. The large earthquake in the Garhwal Himalaya in 1803 AD can be correlated with the terrace abonnement along the MBT, and the great Central and Western Nepal earthquake of 1505 AD can be correlated with the terrace abonnement along the HFT. This shows that the 1803 AD Uttarakashi earthquake reached the eastern Kumaun region up to the Nepal Border and released strain along the MBT, and the great 1505 AD earthquake reached up to the Kumaun Himalaya and released strain along the HFT.

Holocene activity of the secondary strand of the Tanna fault revealed by sediment core analyses and ground penetrating radar profiling, the Izu Peninsula, Japan

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The active left-lateral strike-slip Tanna fault is one of the major faults of the NS-trending Kita-Izu fault zone, which ruptured during the 1930 Kita-Izu earthquake (M_{jma}=7.3). The fault zone is located in the Izu Peninsula, northern tip of the Izu–Bonin–Mariana arc, at about 100 km southwest from Tokyo. In order to reveal the Holocene activity on the Tanna fault, we surveyed the near-surface structure of an offset valley across the fault by radiocarbon dating of sediments obtained from arrayed four drilling cores and ground penetrating radar (GPR) profiling. The drilling sites were located across the NS-trending secondary strand that runs parallel to the northern part of the main strand of the Tanna fault approximately 50 m to the west. The main strand of the Tanna fault was ruptured during the 1930 earthquake, but Holocene activity of the secondary strand surveyed by us have not been revealed in the previous research. The GPR surveys were conducted along the arrays of the drilling sites. The GPR profiling data were collected by common-offset modes using pulseEKKO PRO GPR systems manufactured by Sensors and Software Inc., and we also acquired common-midpoint ensemble data to estimate the electromagnetic wave velocity used in the time-to-depth conversion of the GPR sections. We interpreted several dipping horizons showing sedimentary structure on the geological cross-sections. The horizons were dated by AMS radiocarbon ages of plant fragments and organic soil samples that were measured by Carbon Analysis Laboratory (CAL) and Korea Institute of Geoscience & Mineral Resources (KIGAM). The results explained the Holocene vertical offsets associated with the oblique slip of the Tanna fault. This result of the Holocene activity of the secondary strand parallel to the main strand suggests that deformation along the Tanna fault zone occurs not only on the main strand but also over a broader area. This work was started as a research project funded by the Izu Peninsula UNESCO Global Geopark and supported by Grants-in-Aid for Scientific Research (KAKENHI) JP15K01255 and JP18K03768 from the Japan Society for the Promotion of Science (JSPS).

Distribution of instrumental, historical and archaeological records of seismicity in the Carpathian-Pannnian region

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M>=5, instrumentally recorded earthquakes are displayed on the neotectonic map of the Carpathian-Pannonian region. Additionally, historical data from the past millennium and archaeological data from the past two millennium are shown. Sites from Austria are Roman Carnuntum (next to Vienna) and Magdalensberg (in Carinthia), from Slovenia the old town of Ljubljana and the Roman excavations of Celeia (modern Celje), from Croatia Roman Siscia (modern Sisak), from Hungary the Medieval old town of Sopron, Roman roads of Savaria (modern Szombathely) and Salla (modern Zalalövő), the donjon and churches of Nagyvázsony, the Roman town of Brigetio (modern Komárom), the Medieval donjon and monastery of Visegrád, and from Transylvania the Roman town of Napoca and Medieval churches of Cluj and environs, and the rural church of Inlaceni.

These three kind of data do not show much overlap. Neither is there much connection with faults considered active. There are Austrian and Slovenian sites located along the well-known, seismically active Mur-Mürz Fault and the Periadriatic Fault zone, respectively. All other sites need careful studies to find their causative faults. Historical data inherently carry a lot of human error of the messenger and of the historian who put the information on parchment or paper. Those, who suffered from the earthquake, often see it as overly large, those living far away tend do reduce its significance. Poor localization of the area hit by seismic destruction is common. Precisely located archaeological sites do not suffer from these problems. However, distinction among seismic and non-seismic, natural or man-made destruction is important.

Seismic hazard is routinely assessed based on instrumental and historical data. However, inclusion of archaeological data is imperative. Each of these sources indicate that destructive earthquakes occurred not only along but between known active faults, too. Temporal distribution of seismic events outline 'reliably' active Mur-Mürz Fault, Periadriatic fault zone, and the Vrancea zone; however, most of destructive past earthquakes have very large, centennial to milennial recurrence intervals. Lithospheric stresses, generated by the indentation of the Adriatic promontory into the Alpine range, are alternatingly released at different faults. This is probably a characteristic of intraplate deformation.

Normal fault scarp characterization using convolutional neural network: application to the Trans-Mexican Volcanic Belt

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Fault marker characterization is necessary to understand past fault activity, the physical processes that govern fault rupture. The geomorphological characterization of these markers is currently a time-consuming step with expert-dependent results, often qualitative and with uncertainties that are difficult to estimate. To overcome those issues, we are developing a bayesian supervised machine learning method using convolutional neural networks (CNN) trained on a database of simulated topographic profiles across normal fault scarps, called ScarpLearn. The CNN ScarpLearn is applied to normal fault scarp on topographic profiles perpendicular to the fault. ScarpLearn is able to automatically give the scarp heigth with an uncertainty, and to show the area of the profile containing the scarp. We apply ScarpLearn for the characterization of normal active faults in the Trans-Mexican Volcanic Belt, a across Ameca-Ahuisculco fault system. From this specific case study, and by comparing ScarpLearn with with other methods (non based on deep learning), we explore the progress (computation time, accuracy, uncertainties) that machine learning methods bring to the field of morphotectonics, as well as the current limits (such as bias).

Long-term lateral slip rate of the Yangsan Fault, SE Korea

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The Yangsan fault is one of the seismogenic strike-slip faults within the intraplate interior. Several paleoearthquake surface ruptures were detected along this fault zone, but only one study related to the lateral slip rate was reported. We conducted a geomorphic analysis using the high-resolution (0.5 m/pixel) LiDAR data to determine the lateral offset. To cross-check geomorphic offset, we mapped the lithology distribution of the study area and investigated pebble origin along each stream. Alluvial fans and streams originating from the eastern mountain were displaced by the Yangsan Fault about 300 m right-lateral strike-slip sense. The result of sediment origin analysis is well matched after reconstructing about 300 m left-lateral slip sense. The cumulative lateral slip rate is calculated at 0.32-0.45 mm/yr based on the alluvial fan's burial age (at 850 ka) yield through the cosmogenic nuclides age dating method.

Holocene seismic activity in southeastern Switzerland: Evidence from the sedimentary record of Lake Silvaplana

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High-alpine regions are prone to a large variety of geohazards, among which earthquakes have the strongest impact on landscape and local population. Southeastern Switzerland has few historic earthquake chronicles due to the low population density, resulting in a poorly constrained seismic event catalogue. The aim of this study is to evaluate the paleoseismic activity for southeastern Switzerland by using the sedimentary record of Lake Silvaplana in the Engadine Valley. We use a dense grid of high-resolution 2D seismic profiles, high-resolution bathymetry, and a 10 m long sediment core from the deepest basin to investigate the lake stratigraphy. The bathymetry reveals a flat basin, flanked by steep slopes to the northwest and southeast. The acoustic basement consists of four ridges, and gently-dipping fans to the southwest and northeast. Multiple coevally-triggered chaotic mass-flow deposits have been detected along ten horizons in the seismic data. We interpret these ten event layers to be triggered by paleo-earthquakes in eastern Switzerland or northern Italy. The four most recent of these deposits are cored and radiocarbon dated to ~230, 310, 960, and 1330 cal yr BP, indicating four overregional seismic events that triggered large slope failures in Lake Silvaplana in the last 1400 years. Correlation with sedimentary deposits of Lake Sils, Lake Como and Lake Ledro within radiocarbon uncertainties indicate a large earthquake around 1330 cal yr BP. Within their age ranges, the postulated earthquake at 310 cal yr BP (1640 CE) further correlates with a moment magnitude Mw ~5.4 event in Ftan in 1622 CE, and the 960 cal yr BP (990 CE) with a Mw ~5.2 earthquake in Brescia in 1065 CE. Six mass-movement deposits that were not reached by the sediment core have a suggested age between 7800 and 11300 cal yr BP and are also suggested to be caused by earthquakes. Thus, Lake Silvaplana sediments provide the first reliable record of seismic activity for the mid- and Late Holocene in this region. Basement ridges following the Engadine Line, a major fault zone running along the main valley, further indicate the potential that the Engadine Line is a neotectonically active structure.

Characterization of active segments of the Alhama de Murcia Fault (SE of Spain) by using electric resistivity tomography in ramblas.

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The Alhama de Murcia Fault is one of the most active tectonic faults of Spain. Located southeast of the Iberian Peninsula, this fault is a left-oblique fault, reverse with a strike-slip component, and it was responsible for the last destructive earthquake in Spain. The Lorca earthquake occurred in 2011, killing 9 people and costing about 500 M€. This fault is NE-SW trending, NW-dipping, and 90 km long. Different active segments have been depicted and the maximum related potential earthquake is M ~ 6.4 ± 0.2. In this work, we have carried out an electric resistivity tomography with the aim to determine the spatial location of the fault in relationship with the Quaternary infilling of rambla and alluvial fans. Three profiles have been measured, located in Rambla Vilerda, Rambla La Hoya, and Rambla Lebor. The Vilerda profile was measured in a W-E direction, with an electrode separation of 15 m and 1200 m long. We used different configurations: Wenner, Schlumberger and Dipole-Dipole. The La Hoya profile was measured using an electrode separation of 15 m, and 1720 m long, NW-SE direction, and using a Wenner configuration. At Rambla Lebor, a profile with 15 m electrode separation 1200 m long and Wenner configuration, was measured following the rambla direction; due to the noisy character of the profile, mainly at its end, a new one with 5m electrode separation, 400 m long and Wenner configuration, was carried out in order to confirm the results obtained. The profiles show that the Alhama de Murcia Fault is composed of a series of vertical faults partially sealed by current deposits, which generally show a reverse component towards the surface. Fault activity is observed by changes in the depocenters of subactual deposits. The Vilerda profile in the SW zone of the fault shows a vertical displacement greater than 150 m. This throw fault is higher on the Rambla La Hoya and drops to a few tens of meters on the Rambla Lebor.

Investigation of vegetation change through fossil pollen from Anatolian peatlands: Golbasi lakes

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Fossil pollen analysis provides a valuable proxy for investigating the effects of human activities on the natural environment. This research area has undergone major changes in forest areas in southeastern Turkey, located in the transition zone between the Irano-Turanian and Mediterranean phytogeographic regions in the east of the Mediterranean basin. This region of lakes (Gölbaşı, Azaplı, İnekli) has a stepped relief feature consisting of high mountain areas around it. The interconnected lakes are among the ecologically important wetlands of Anatolia. In the pale coastal areas of the lakes there are peat formations exceeding 1 meter.

The aim of this study is to reconstruct the changes in Quaternary vegetation fossil pollen analysis. A 21 m long core was taken from the peat bog in the north of İnekli Lake in the study area. This study contains the first findings of the research. In this study, Carbon-14 dating will be made in sediment samples and changes due to human influence will be revealed, especially in the Holocene.

Key words: Fossil pollen analysis, Paleovegetation, Holocene, Human activities, Anatolia.

Sediment records suggest post British-invasion declines in diversity of wetland plant communities in the Koondrook-Perricoota Forest, Murray River, NSW

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Floodplain wetlands support enormous biodiversity and a range of other vital ecosystem services. However, these wetlands are threatened by a range of processes. In the Murray-Darling system of southeast Australia, these processes include altered wetting regimes, cropping, grazing and invasive species. Detecting and monitoring changes to these systems is limited by poor benchmark data, which would otherwise provide the basis for establishing the degree and nature of changes as well as possible drivers. This study sought to establish benchmark conditions and temporal patterns of change in wetland plant communities by examining stratigraphic changes in preserved plant and animal remains and viable seeds of wetland plants, taking advantage of the capacity in many wetland plants for seeds to remain viable in the sediment for many years and to subsequently germinate upon wetting. Sediments from 12 wetlands in the Koondrook-Perricoota Forest were sampled at 2 cm intervals to depths of 30 cm to 40 cm. Lead-210 dating of the sediment profiles suggest the upper 10 to 16 cm of these records were deposited in the last century.

The preserved remains assemblages of the pre and post-invasion period were generally distinct, though the degree of change varied among wetlands. In general, the post-invasion period is characterised by declining richness and diversity and abundance in charophyte oospores in several of the wetlands. The seed banks trials showed general patterns of decline in seedling abundance, richness and diversity with depth, consistent with expected age-depth declines in seed viability. However, deviations from the pattern of decline-with-depth were observed in some wetlands and for some taxa, suggesting the abundance, richness and diversity of the seed bank has declined in the last century. While the specific cause of these changes is uncertain, they are likely a response to reduced flooding as a result of flow regulation and water abstraction. In the case of the apparent declines in charophytes, introduced grazers such as cattle could well have been a factor given that trampling and increased turbidity arising from their presence in and around the wetlands is likely to have been detrimental to these submerged plants.

Plants maintain climate fidelity in the face of dynamic climate change

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Plants will experience considerable changes in climate within their geographic ranges over the next several decades. They may respond by exhibiting niche flexibility and adapting to changing climates. Alternatively, plant taxa may exhibit climate fidelity, shifting their geographic distributions to track their preferred climates. Here, we examine the responses of plant taxa to changing climates over the past 18,000 y to evaluate the extent to which the 16 dominant plant taxa of North America have exhibited climate fidelity. We find that 75% of plant taxa consistently exhibit climate fidelity over the past 18,000 y, even during the times of most extreme climate change. Of the four taxa that do not consistently exhibit climate fidelity, three – elm (*Ulmus*), beech (*Fagus*), and ash (*Fraxinus*) – experience a long-term shift in their realized climatic niche between the early Holocene and present day. Plant taxa that migrate longer distances better maintain consistent climatic niches across transition periods during times of the most extreme climate change. Today, plant communities with the highest climate fidelity are found in regions with high topographic and microclimate heterogeneity that are expected to exhibit high climate resilience, allowing plants to shift distributions locally and adjust to some amount of climate change. However, once the climate change buffering of the region is exceeded, these plant communities will need to track climates across broader landscapes but be challenged to do so because of the low habitat connectivity of the regions.

Spatial explicit, quantitative reconstruction of past vegetation based on pollen or charcoal data as a tool for autecology of trees

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The determination of autecological preferences based on long-term vegetation dynamics is hampered by the lack of realistic estimates for past occurrence and abundance patterns. Palaeoecological record has still rather character of points than spatially continuous maps.
To infer long-term autecological preferences of trees from reconstructed vegetation. Compare reconstructions based on independent input data.
We employed to the regional training set of 60 sites the Extended Downscaling Approach (EDA) using nine topographic factors clustered in 8 habitat classes, data on pollen productivity estimates, fossil pollen, charcoal sequences from soil and archaeological contexts. Based on abundances and habitat preferences from the last 9 millennia, we calculated the autecological preferences of tree taxa, using multivariate statistics.
The significant spatiotemporal patterns between soil-charcoal and pollen-based EDA validated the reconstruction, the use of both records in the EDA, and the EDA model itself. One of the topographic indices - vertical distance to channel network - evidenced the following: the closest taxon to the groundwater is Picea; Abies, Betula, Pinus, Quercus have intermediate distances; Fagus grows far from the channel network and Corylus even further.
The EDA model linked past forest composition to realistic topography. Such a spatially explicit reconstruction produced by our new algorithm allows inferring the relationship between past plant communities and environmental variables. The long-term preferences of tree species to habitat characteristics match their current autecological demands. This might a breakthrough in quantitative plant paleoecology.

When geodiversity drives biodiversity: Bagno dell'Acqua alkaline lake, Pantelleria Volcano, Sicily, Italy

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Bagno dell'Acqua Lake is part of the Pantelleria Island National Park (Sicily) and represents a site of extraordinary environmental and scientific relevance as the interactions between volcanic fluids, climate and morphology make the chemistry of the waters alkaline, with the development of rich biotic communities and of a very specific ecosystem, unique in Italy and rare in the world.

In recent years, the lake has been the subject of highly multidisciplinary and interdisciplinary studies which concerned almost all the microbial, faunal, geomorphological, hydrogeological, volcanological, geochemical and minero-petrographic aspects of the lake.

The lake has a sub-circular shape (350x450m), the maximum depth is slightly more than 12m. The composition of the water is controlled by the meteoric contribution and groundwater input, mixed with seawater and hydrothermal springs. Hydrothermal emissions are present along the entire perimeter of the lake and on the seabed. The gas emitted is mainly CO_2 (98%). The waters of the lake are rather homogeneous, with temperatures of 14-25°C and pH about 9. Lake Bagno dell'Acqua is the only alkaline volcanic lake in Italy and the only non-glacial one in Europe.

The most characteristic biota of the Lago Bagno dell'Acqua ecosystem is that of cyanobacteria, which represent the first level of the aquatic food chain and contribute to the biodiversity of the lake together with a vast range of other microbial organisms; the bacteria cover the seabed with thick felts, are responsible for the formation of a characteristic organic mud responsible for the white/turquoise color of the seabed (however back and anoxic immediately below the water/sediment interface) and generate microbialites (organo-sedimentary deposits with a relevant mineral component) along the shores and inside the lake.

From the point of view of biodiversity, the geological structure and the particular chemistry make the lake of Bagno dell'Acqua a real extreme environment and a biodiversity hot spot with characteristics that are unique in Europe and exceptional in the world. Biodiversity is always based on geodiversity (the set of geological structures and processes that determine the physical and chemical environment), but this interaction is particularly evident in extreme environments such as Bagno dell'Acqua lake.

Global drivers impact on geodiversity and geosystem services in Alagna Valsesia (Monte Rosa, W-Alps, Italy): Mapping and assessment for a sustainable development perspective

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Over the last century, human activities and global drivers of change have added disequilibrium factors to the natural hazards occurring in mountain regions, deeply affecting them by resulting in huge alterations in the balance of these environments. One of the most visible effects of rising temperatures is the melting of glaciers, with a trend towards thinning and retreat of glacier fronts, leading to a change in pressure on contiguous slopes, and increasing their instability, thus proving to be a trigger for mass movements. Other evident effects are related to permafrost degradation and the growth of erosion in previously glaciated areas. These changes have an impact on increasing of natural hazards and in causing loss of geodiversity and ecosystem services, thus demanding the need to develop new conservation strategies to support mountain regions taking care of geoheritage protection. To better investigate how climate change and human activity impacts affect the geoheritage and the benefits that geodiversity provide to society we focused on Alagna Valsesia municipality, the highest elevation area of the Sesia Val Grande UGGp. Here we collected and examined available data in a GIS environment to map the geodiversity in the study area, recognize the geosites and assess them to understand the value of the present geoheritage. Geodiversity map has been used to evaluate and identify the ecosystem services. Regulating, provisioning, knowledge, cultural, and supporting services have been identified, with a broad view on evolutionary scenarios of human-nature interactions. Evaluation of global drivers of change allow us to understand the impact of the changes on services, and DPSIR approach, linked to geosystem services, led us to address the need of a strong planning and management strategies for the Sesia Val Grande UGGp and for sustainable development of human exploited and naturally vulnerable mountain regions, considering actions to promote geotourism. This approach provides the basis for understanding the natural and human-induced threats to geodiversity and makes it possible to consider geoheritage in planning and management to foster sustainable development actions.

Potential factors influencing past vegetation composition on Hallands Väderö island, SW Sweden

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Palaeoecological analyses over the last c. 3000 years have been carried out on Hallands Väderö, an island nature reserve situated off the south west coast of southern Sweden. The sample site is a small pond containing some of the oldest *Quercus, Tilia* and *Fagus* individuals present in Sweden and is characterised by a remarkably rich biodiversity of fungi, bryophytes, lichens and insects.

For exploring the relative importance of main drivers on forest composition, we statistically compared our palynological results with independent datasets of climate variations (winter temperature and relative summer humidity reconstructed from tree ring data) and fire activity (based on macrocharcoal data) over the last c. 1000 years. Furthermore, a unique historical record of numbers of grazing animals on the island since AD 1665 was used to explore the effects of domestic stock on selected important plant taxa.

The statistical analyses suggest that during the last millennium warm winter temperatures and summer humidity account for most of the variance for *Quercus, Alnus, Tilia* and *Corylus*. Instead, grazing was the main factor reducing population size of *Fagus, Alnus, Tilia* and *Corylus* on the island over the period AD 1665–2000, highlightening the importance of browsing for tree species composition.

We conclude that the survival of large numbers of red-listed species on Hallands Väderö is likely to be due to the continuity of large old trees, ancient forest composition and a distinctive disturbance history in a favourable climate. The deciduous trees associated with high levels of biodiversity among epiphytes and saprophytes that characterise the island make its future management of national significance.

MeSCAL Project: biodiversity and cultural heritage in southern California landscapes. A palaeoecological approach

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Mediterranean cultural landscapes have been built through time as a consequence of climatic and natural dynamics, as well as by anthropic processes such as migration, trading or colonial settlement. Land-use changes and the introduction of new socio-economic and cultural patterns had serious impacts on local ecosystems, biodiversity and floristic richness. While studies about the consequences of these interactions are still scarce in southern California (SoCal), the MeSCAL Project has been designed to fill this gap. The Californian coast is a biodiversity hotspot attesting to a rich history of human settlement over the last ~13ky. MeSCAL Project will analyze the spatial distribution of land-uses and plants following Late Holocene (~4ky) migratory and colonial processes, assessing their impact on SoCal native flora, biodiversity and landscape structure.
The MeSCAL Project proposes an interdisciplinary approach based on the combination of 1) multi-proxy palaeoenvironmental analyses –i.e. pollen, non-pollen palynomorphs (NPPs), fire history analysis, diatoms, sedimentology, geochemistry– in continental wetlands and marine records, providing local and regional information on vegetation and land-use changes; 2) calibration of fossil palaeoenvironmental datasets with modern analogues of vegetation and land-uses; 3) archaeobotanical analyses addressing information on past consumption and use of plants; and 4) comparison of paleoenvironmental results with archaeo-historical and ethnographic datasets. MeSCAL Project includes a micro-regional approach, with case-study locations distributed along a coastal-inland transect which also provides a local-scale perspective. This will allow a better understanding of the different landscape changes in areas under direct colonial control and those with smaller colonial influence. The MeSCAL Project will help to calibrate how human mobility and settling shaped the current SoCal landscapes, measuring the long-term impact of transported plants and introduced practices over the biodiversity in this territory marked by human migrations and colonial processes. As well, it will help to place value on the cultural heritage reflected in Californian landscapes, engaging citizens with their own history and identity through the environment they inhabit, and will provide information about ancestral land-uses. This will help to protect native cultural identities and traditional ways of life, but also provides tools for landscape management and the protection of his biodiversity hotspot.

Late Quaternary bioerosion pattern controlled by upwelling events: a case of study in Puerto Lobos (San Matías Gulf, Argentina)

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The ichnological analysis of Quaternary marine deposits in Argentina has increased in the last decade; however, despite the geographic extension of these deposits, the studies continue to be scarce. In Puerto Lobos (San Matías Gulf -SMG-, Argentina), these deposits are represented by six beach ridges, parallel to the coast, which provide complete information since the Pleistocene. Recently, an ichnological study from Quaternary deposits from Patagonia described bioerosion traces in Puerto Lobos in shells from *Crepidula*. Nevertheless, there has not been an ichnological analysis that includes the diversity of molluscs present at this locality. Here, we describe the bioerosion recorded in shells from different taxa of molluscs from Quaternary marine deposits from Puerto Lobos. A total of 710 shells were observed in a *stereoscopic microscope* to register the absences/presences of bioerosion traces. As a result, more than 12 ichnotaxa are recorded for the first time, including macro- and microbioerosion traces, which allows us to interpret which environmental factor controls the bioerosion pattern in this area. The most abundant ichnotaxa from the Pleistocene are *Caulostrepsis* and *Entobia* while the Holocene and modern samples are characterised by *Iramena*, *Podichnus*, and *Oichnus*. The differences between the bioerosion pattern during the Pleistocene and Holocene-Modern suggested changes in the environment. The SMG presents upwelling coastal events that foment biological productivity. Palaeontological studies from northeast SMG suggested that this upwelling process is present since the Holocene in the gulf. Therefore, the increase in bioerosion traces produced by bryozoans together with a rich ichnodiversity in the Holocene samples could be related to a rise in nutrients, and not to a change in water temperature (lower Sea Surface Temperature) as has been interpreted in other Patagonian areas. Finally, the low decrease of ichnotaxa in the modern samples could be related to the northward movement of the Brazil-Malvinas Confluences in the mid-Holocene. In conclusion, the variation in the abundance and ichnodiversity in bioerosion traces during the Quaternary in Puerto Lobos are due to oceanographic conditions related to upwelling events that facilitated the availability of nutrients. These results are consistent with previous works in the SMG region.

Late Pleistocene paleowetlands in semiarid dunefields, Western Pampas of southern South America

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Hydromorphic features, like rhizoliths and lithological properties of rocks/sediments, are indicators of special hydrological conditions in past environments, like variations in soil saturation, drainage, water table depths. They can be related to distinct landscapes and/or climatic conditions. The presence of these features in the Quaternary record of today drylands are key elements to infer wetter than present conditions. Among these features, rhizoliths are conspicuous megascopic structures that appear as root traces of massive or concentric-like mineral precipitations. They result from a total or partial replacement of root organic matter and indicate a paleolandscape with a high colonization of vascular plants. The Western Pampean Dunefield of central Argentina (34ºS, 65.3ºW), southern South America, is characterized by blowout dunes, several of them with km-long diameters, and showing superimposed smaller dunes over their depositional lobes. This eolian landscape is, at present, mostly stabilized by a savannah-like vegetation cover and agriculture fields. It exposes a record of profuse eolian activity along different periods of the late Pleistocene (~50-17 ka) and during most of the Holocene (~12-1 ka). A today notorious aspect of this dunefield is the hydrological state of the deflation basins of the blowout dunes, while in the eastern flank these basins commonly host shallow lakes, formed during, at least, the last millennium, in the western area the blowout dunes are dry, vegetated landscape. The sedimentary record at some blowout dunes includes hydromorphic features, including carbonate and ferruginous rhizoliths and calcareous crusts. They appear at a paleoshoreline position of current perennial shallow lakes, but also in blowout basins without a vestige of any kind of wetland during, at least, the last ~100 yr. The integration of geomorphology, sedimentology, micromorphology, and chronostratigraphic data allow defining/interpreting the sedimentary facies hosting the rhizoliths and related deposits, in the context of a dominated eolian landscape, and to discuss the geomorphological, climatic, and ecological conditions which allowed the formation of wetlands (lakes?) in such inland dunefields during, we infer, the deglaciation times.

Geochemical behavior and water age of multilayer aquifer in Andean valley of Cauca-Colombia: water use and availability in the present and future.

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The studied area is located in the south-west of Colombia in the Cauca valley, close to the city of Cali, between the Western and Central Andean Cordilleras. The climatology is intermountain high plain type (Tannual=24°C, P=1400mm/y), the altitude is between 900 and 1000 masl. It is limited in the West by the Cauca River and in the East by the mountainside of Central Cordilleras with a maximum width of 30 km. The unconfined aquifer is composed by quaternary alluvial deposits brought by the Cauca river and other tributaries issue mainly from erosion of Andean volcanic formation and forms downstream a multilayer aquifer. This aquifer is formed by 2 levels, the upper level, A, and the lower level, C, which are separated by a continuous clay layer B differentiated only in the area close to the Cauca River, that implies upstream A and C are not distinct. The estimated annual recharge is about 270 Mm3 and takes place mainly in the alluvial cone based on the analysis of water isotope and possibly for a few part through the fault system which is standing in the Western and Central Cordilleras. The regional water flow is East-West, in direction of the Cauca River. The chemical results show a calcic bicarbonate facies in level A and in the highest undifferentiated zone linked to the regional geological silicate formation and a chemical evolution in confined level C characterized by the substitution of Ca^{2+} by Na^{+} (ion exchange process) through the layer clay B, and by chloride values increasing with time in the deepest boreholes in relation to the Tertiary marine formation located under the alluvial deposit. Based on carbon-14 measurement the confined part shows higher residence time from upstream to downstream, close to the Cauca river some boreholes were artesian in the past and with their intensive use, in particular the intensive cultivation of sugar cane, they lost this characteristic confirming a low renewable rate. On the opposite the residence time in the level A (14C and tritium), is younger with ages post nuclear atmospheric test. Inside this aquifer a differentiated water management is necessary

A detailed Holocene fire history reconstruction from the Araucaria forest and Grassland (Campos) vegetation mosaics in southern Brazil

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The forests-grassland vegetation mosaics in the *Araucaria* region of southern Brazil are hypothesised to be strongly controlled by fire. However, a fire history with sub-decadal resolution is hitherto not available and therefore detailed millennial-scale interactions between vegetation and environmental changes are largely unknown yet. To close this knowledge gap, we studied the well-dated 11-m long Holocene sediment infill of Lagoa Dourada, a small lake in the Paraná State highlands. Here we present the first high-resolution macroscopic charcoal record from this region that documents past fire-regime changes. We found that the amount of biomass burned was highest around 9500-8000 and 6300 cal BP, moderate around 5500-1000 cal BP, and increased during the past 100 years with land-use change. We will discuss interactions between fire and vegetation for two periods; one in the mid-Holocene between 7000-6200 cal yr BP and one in the late Holocene between 3300-3000 cal yr BP where pollen was analysed at the same high resolution as macro charcoal.

The coastal confined aquifer of the Golf of Uraba (Colombia), geochemical evolution and residence time : towards a rational water use.

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The coastal confined aquifer in the Gulf of Urabá (Colombia) is an important water source for the banana agro industry as well as for urban and rural communities. Located in the north western of Colombia, under a tropical humid climate controlled by ITCZ (Tannual=28°C, P=2100-3800mm/y North-South), the study area covers 1,030 km^2 characterized by a smooth rolling topography, 0-200 masl until the Abibe hill (East limit, 30 km from the sea). The main surface water network flows across the León River basin, which discharges into the Gulf of Urabá and represents the South border. In northern part a geological barrier limits the aquifer extension.

The geology consists of Quaternary alluvial (Qal) deposits (phreatic aquifer) overlain on a sedimentary Tertiary sequence, the Corpa Formation (Pliocene), whom the confined aquifer (T2B) is limited by 2 aquitards, bottom (T2A) and top (T2C), crops out in the western flank of the Abibe aera which is also the recharge zone.

Hydrochemical analyses and stable isotope monitoring were conducted to determine its funcioning and its age, and the main processes governing groundwater chemistry.

The flow direction of the confined aquifer is East to West (Pacific ocean), with local artesianism close to the coast. The main hydrochemical processes are the silicate weathering and the dissolution of secondary carbonates. The samples close to the recharge zone, are generally characterized by their low mineralization with a HCO_3^-–Ca^{2+} facies. Along the flow direction TDS/EC increases and chemical facies is predominantly HCO_3^-–Ca^{2+}/Mg^{2+}; this system evolves to a HCO_3^-–Na^+ water type closer to the coast. The larger contribution of Na^+ with respect to Ca^{2+} indicates the influence of the ionic exchange process. $\delta^{18}O$ and δ^2H compositions combined with ^{14}C data highlight the difference in climatic conditions between the recharge zone and the confined section of the aquifer. ^{14}C ages give recent to 28,300 years BP in accordance with the more depleted water isotopes in flow direction suggesting a cooler recharge than the current climate conditions corresponding to the last glacial period (late Pleistocene). Despite the high local pluviometry the coastal part of the confined aquifer is non-renewable and its use should be monitored.

Linking Andean paleo-landslides to the probable triggering seismic source (31°–33°S)

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Landslides are maybe the most striking seismic environmental effect which impact scales with earthquake magnitude. However, the determination of the seismic source of paleolandslides is not fully understood, being a matter of discussion. In seismically active mountain regions, large-volume landslides clustered along active faults are assumed to be coseismic. Thus, shallow crustal earthquakes from nearby active faults assumed as the most likely source of slope collapses. To investigate this hypothesis, several prehistoric landslides in the Arid Central Andes were geomorphological, geological, and geotechnical studies. Newmark-type, limit equilibrium, and numerical modeling back-analyses methodology were also conducted. This methodology allowed us to identify the potential sources of earthquakes that may have induced the studied gravitational process. Moreover, the chronology obtained for some of these landslides disallows a probable climate forcing on slope instability in this arid region and our finding extends the regional neotectonics until the Late Pleistocene.

Last termination and Holocene Forest history and climate changes on the eastern slopes of the central Patagonian Andes

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We report pollen and macroscopic charcoal records from lake sediments we retrieved from Lago Mano Negra (LMN, 45°23'S, 71°55'W, 840 masl) to document the vegetation, fire, and climate history east of the Andean divide in central Patagonia since ~18.5 ka. Our aim is to decipher the functioning of terrestrial ecosystem changes and their response to variations in Southern Westerly Wind (SWW) influence. The pollen record from LMN shows a gradual *Nothofagus* increase starting at ~18 ka, along with hygrophilous and cold-tolerant conifers characteristic of modern North Patagonian Rainforests (*Pilgerodendron uviferum*, *Podocarpus nubigena*) currently present along the humid coasts of western Patagonia. This portion of the record suggests an initially open landscape followed by arboreal encroachment under humid and cold conditions. The conifers reached maximum abundance between ~14.5-12.2 ka in the context of *Nothofagus*-dominated woodland, indicating peak precipitation regime. A sudden increase in *Nothofagus* at ~12.2 ka led to the establishment of closed-canopy forests, along with declines in hygrophilous and cold-resistant trees, herbs, shrubs, and peak fire activity, suggesting warm and dry conditions that persisted until ~11 ka. Highly resilient *Nothofagus* forests have lingered since then near LMN despite frequent explosive volcanic events and fires. European/Chilean disturbance started at ~0.2 ka in the form of deforestation along with increases of herbs and non-native plant taxa (*Rumex*, *Plantago*, *Pinus*). Our results suggest that scattered populations of rainforest trees inhabited the eastern periphery of the Patagonian Ice Sheet during the Last Glacial Maximum and that the early afforestation of this region started east of the Andes and proceeded westward into the Chilean channels and archipelagoes. The precipitation variations suggest strong influence of the SWW during the Last Termination, with a maximum influence between ~14.5-12.2 ka, followed by a weakening during the first millennia of the Holocene. Recent large-scale deforestation caused by human activities drove to the largest-magnitude shifts seen since 11 ka.

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Paleoenvironmental and climatic reconstruction in the central region of Argentina during the Quaternary: stratigraphic section Río Carnero, Córdoba

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The eastern piedmont of the Sierras de C󠀠órdoba, central Argentina, is characterized by numerous outcrops of the fluvial to eolian succession of the Quaternary, whose paleoclimatic and paleoenvironmental values are still poorly studied. In particular, along the Río Carnero, the stratigraphic succession is composed of fossiliferous loess layers, paleosols, and fluvial sediments. We selected some sections along the Río Carnero to study using a multi-proxy analysis considering sedimentological, geochronological, malacological, and stable isotope data to reconstruct the past environmental conditions and the origin of the loess deposits. The loess sequence is rich in well-preserved *Epifragmophora* sp. that are particularly well suited for geochemical studies and inform us about local climatic conditions at the time of loess deposition. Preliminary radiocarbon dating suggest that the loess was deposited during MIS2-3. Geochemical analyzes (major and trace elements) and 87Sr/86Sr allow conclusions to be drawn about the origin of the loess particles and the impact on the past environment. Preliminary results show that the sequence begins with massive reddish-brown sediments composed of strongly bioturbated loess. Silty-sandy sediments continue across a clear boundary with fine sand and gravel interbeds and clay layers that average 4-5 m thick with calcareous concretions and irregular accumulations of tosca. Overlying this level are the remains of an eroded paleosol, partially covered by recent sandy sediments or showing the development of incipient soil. Geochemical analyzes are in the execution phase. This work highlights the importance of the study in continental mid-latitude sectors for the knowledge of glacial and interglacial periods, the contribution of which is fundamental to the understanding of environmental evolution during the Pleistocene and Holocene at regional and global scales.

Incorporation of anthropogenic materials in beachrock on Eleuthera Island through fast carbonate cementation, Bahamas

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The abundance of anthropogenic debris along coastal regions is significant enough to start being preserved into the sedimentary record. Carbonate beachrock, which are bodies of beach sediment cemented with carbonate minerals, are useful archives of coastal evolution and also provide physical barriers to coastal erosion. Beachrock formation is known to permanently alter the morphodynamics of a coastline and lock sediment in place, while reflecting wave energy. The cementation forming beachrocks occurs on a scale of years or less, but observations of very young beachrocks with well constrained ages are still rare.

This study documents the first recorded instance of cemented anthropogenic debris on Eleuthera Island, the Bahamas. These debris, including fragments of man-made glass, and rubber/tar were found cemented into dissolution pockets of Holocene aged beachrock exposed along the modern-day coastline on the windward side of the island. Although our understanding of modern cementation processes is limited, observation on beachrock cemented debris will inform relationships between topographic heterogeneity along modern shorelines and coastal sediment erosion/accumulation.

In this study, we characterize and quantify the amount of anthropogenic materials being transported to coastal areas of Eleuthera Island and are incorporated by beachrock. We compiled previous work documenting anthropogenic pollution across coastlines around the globe and queried data by material and the relationship of the debris to a rock interface. The increasing frequency of debris found in beachrock and plethora of unconsolidated plastic found globally across beaches warrants a new classification scheme for anthropogenic "sediment" cemented into coastal cementation processes. Here, we discuss how anthropogenic debris is being preserved in carbonate coastlines. Implications of this work will feed into a new anthropogenic debris transport model for deposited anthropogenic material kept from drifting off to the open ocean. These results recognize that more robust efforts towards understanding modern-day cementation of anthropogenic debris will be major considerations in modelling future coastal changes and also have legal and regulatory implications regarding proper disposal and accountability of anthropogenic debris.

Climatic and hydrological impacts on a coastal subsiding plain: The case of Sybaris Plain

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Coastal and deltaic plains represent vulnerable environments affected by natural processes (e.g. land subsidence, sea level rise, saltwater intrusion, and marine intrusion). Their impact is often exacerbated by increasing human-induced pressure due to land-use and hydrological changes. The Sybaris Plain (Calabria, Italy) represents a perfect case study for the analysis of environmental and climatic changes that occurred in a coastal subsiding plain in southern Italy during the Holocene.

A series of plain drillings was carried out to better locate the construction of a new highway as the territory is often flooded. On the basis of preliminary pollen and radiocarbon analysis the core S4 Bis (40 m long) was selected and a new complete core S4 Ter (39°73'N; 16°40'E, at 13 m a.s.l) was recently drilled to the same depth. The new core is now under study for the paleoenvironmental reconstruction through magnetic susceptibility, tephra, radiocarbon, microfauna and pollen analyses.

However, in order to deeply analyse the interactions between past populations and vegetational changes in the area through time, it is of primary importance to consider on-site pollen records from the plain. The plain hosted the Early and Late Neolithic site of "Favella della Corte", located in the middle of the coastal plain (39°68'N; 16°45'E), at 14 m a.s.l. The quaternary terraces around the plain were the seat of many Bronze and Iron Age sites. The plain was afterwards part of the agrarian and funerary landscape of the Greek colonies of Sybaris and Thurii, and of the Roman colony of Copiae, followed by a marshy Medieval and early modern phase.

Results of pollen analysis show an open environment dominated by herbaceous plants, in combination with a strong presence of microcharcoals and fungi spores. Swamps correlated to high-water tables are indicated by fern spores. Pollen signals are closely influenced by past water channels and artificial drainages. Vegetational indicators, integrated with the perspective of the historical trajectory, show resilient strategies adopted by archaic populations such as a model for a future water management in recent times.

A palaeoecological evaluation of Typha as a potential tool for wetland management in New Zealand. Part 2: cultural perspectives

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Following the depletion of ~80% of New Zealand's (NZ) wetlands during the last 150 years, there is now a concerted restoration effort motivated by cultural, ecological and economic sustainability aspirations. Archaeological and palaeoecological records can inform this effort by providing valuable insights around indigenous practices and traditional ecological knowledge (TEK). Here we draw upon palaeoecological and anthropological records to trace the history of the wetland plant *Typha orientalis* (raupō) and consider its cultural significance in human-wetland interactions.

Along with the other ~40 species or hybrids of *Typha* worldwide, the NZ species is culturally iconic and has provided a rich source of food and materials for prehistoric peoples. We explore the wide range of reported usages of *Typha* by Māori, which shows strong synergies with usage by other traditional societies globally. In parallel, we are developing new pollen records from across NZ that consistently show the co-expansion of *Typha* and human settlement. NZ's short and recent prehistory reveals an apparent eco-cultural symbiosis between plant and people, whereby *Typha* expansion was both promoted and utilised by traditional Māori society up to and including the early European era. Together these anthropological and palaeoecological records raise questions as to the extent to which *Typha* was deliberately managed by Māori, including translocation by migrating tribes, and the extent of indigenous inter-generational knowledge and understanding acquired through these practices.

Our observations bring an additional, cultural, perspective to the role that *Typha* can play in wetland bioremediation, beyond promoting biodiversity, ecosystem health and resilience and carbon sequestration. In traditional Māori society, the health and vitality of communities and wetlands are inextricably linked and there is growing appreciation that NZ's modern conservation practice can be significantly empowered when it is allied with TEK. Our paleoenvironmental records suggest that it is possible for ecosystems and people to live and thrive alongside each other, supporting the contention that wetland restoration efforts will be more successful when they are culturally-informed. In a separate presentation at this congress, we show that a better understanding of *Typha's ecological* response to anthropogenic disturbance in prehistory can also help to guide wetland restoration strategies today.

Millennial-scale dynamics of pastures and livestock in the Central Pyrenees, NE Spain. A transdisciplinary approach

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In the current Global Change context, with a warming climate and an on-going abandonment of traditional land uses, mountain areas face a challenging future and science-based management is needed to ensure the sustaining of their unique socio-ecosystems. Management plans should include long-term approaches, but they are commonly poorly integrated in environmental policies. For example, in the Pyrenees, to maintain a sustainable equilibrium of extensive livestock pastures a balance between an adequate grazing pressure to preserve biodiversity and traditional land uses is needed to avoid bush encroachment of subalpine and alpine pastures. However, little is known of when and how these cultural landscapes began, and how they have changed through time.

We present in this contribution, PASTORA, a transdisciplinary project focused on tracing the origin, determining the resilience patterns and the use of different subalpine and alpine pastures over time at the Central Pyrenees (NE Spain). The approach includes the combined use of several traditional and innovative palaeoecological tools: i) fossil pollen, *sed*aDNA and phytoliths from Holocene lacustrine sequences, ii) archaeological data since Neolithic times, including sites location and evidences of human presence, but also socio-economic practices extracted from dental micro-wear analyses of domestic animals, and iii) modern ecology techniques such as satellite geo-location livestock tracking next to traditional vegetation surveys of pasture plots.

This methodological approach will allow us to generate an integrated space-time vision of mountain pastures, reconstructing past history of the grasslands, determining the palatability of the grasses preferentially used at the beginning of the Neolithization in the Pyrenees, and quantifying the main grassland community shifts occurred since its origin. In addition, we will characterize the impact of the early livestock farming on the landscape by identifying changes in animal density, the dominant type of livestock in different periods, the social responses to environmental changes and the functionality of the pasture ecosystems for the last 8000 years.

Living on the Edge: surviving and thriving in the Holocene Humberhead Levels.

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The Humberhead Levels currently exists as a flat, lowland area that today is mostly used for the purpose of arable agricultural. For the majority of the Holocene however, the landscape looked drastically different. Prior to drainage works in 1626 AD, the area of the Humberhead Levels existed as a wetland environment featuring a complex system of rivers and streams. Archaeological evidence has shown the Humberhead Levels was attractive to human communities during the prehistoric, with lithic evidence for human occupation during the Mesolithic, Neolithic and Bronze Age situated near relict river courses and channels. Throughout the historic period, up until the drainage of the landscape, the economy of the area was one of traditional pastoralism, with residents using the seasonally flooded land for pasture and continuing exploitation of the wetland's natural resources. While there have been previous investigations into the archaeology and environmental history of the Holocene Humberhead Levels, the complex relationship between the palaeoecology of the landscape and human occupation and land-use has not been heavily investigated. This project examines the relationship between the changing blue-green landscapes of the Holocene Humberhead Levels and the human communities that thrived within them using a multi-disciplinary palaeoecological, archaeological and historical approach. With growing pressure for the restoration of blue-green landscapes today, understanding how human communities can exploit these areas sustainably is becoming increasing more important. The research of this project will be helpful for not only developing a better understanding of how human communities lived in the Humberhead Levels during the Holocene, but also for identifying possible ways in which human communities can live within blue-green landscapes today using subsistence practices of the past.

Can we use chemotaxonomy to reconstruct past food practices in Australian Aboriginal communities?

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Across Australia, land management changed drastically after the arrival of Europeans, often leaving scarce evidence of the previous Indigenous cultural practices-. Because of this drastic change, the reconstruction of past landscapes and environmental conditions in pre-colonial Australia is not always straightforward. – Ethnobotanical and historical archives describe the use of yam daises (*Microseris lanceolata*, 'murnong'– Asteraceae Cichorioideae) as a staple food by Aboriginal Australians during pre-colonial times, indicating that local communities modified ecosystems for land exploitation and food production. Some palynological records from southeast Australia confirm the abundant presence of pollen types from the Asteraceae Cichoroideae subfamily. Nevertheless, accurate identification at the species level in the Asteraceae family is challenging. Most Cichoroideae pollen grains are indistinguishable under the light microscope and/or scanning electron microscope, meaning that the long-term dynamics and distribution *Microseris* plants cannot be explored yet using traditional palynological records.

Previous studies have successfully classified modern pollen grains of cryptic taxa (e.g. *Quercus* and Poaceae species) using their chemical spectra obtained by Fourier Transform Infrared (FTIR) spectroscopy. We have developed a modern library of FTIR spectra for taxa classification from native and introduced Asteraceae Cichorioideae species commonly found in Australia. Our dataset includes some introduced species and all the native daises of southeast Australia (e.g. *Taraxacum officinale, Reichardia tignitana, Hypochaeris radicata, Picris angustifolia, Hieracium praeltum, Sonchus hydrophylous, Picris aquarrosa, Cymbonotus lawsonianus, Taraxacum aristum, Acites megalocarpus*), including *Microseris* taxa (*Microseris lanceolata, Microseris scapigera* and *Microseries walteri*) from herbaria archives. We focused on the chemical fingerprint of single pollen grains, which have been treated with standard palynological procedures, and achieved classification success ranging from 55% to 75% at species level. Our results suggest that this approach can successfully classify sub fossil Asteraceae Cichorioideae pollen to species level. The implementation of this methodology can enhance archaeological and palaeoecological investigations around plant exploitation and land-use change in pre-colonial Australia and beyond. A deeper understanding of pre-colonial landscapes and the ecological effects of Indigenous Country-keeping practices can pave the way to more sustainable approaches to land management.

Towards a holistic understanding of past, present, and future human-animal-environment relationships in the Central Murray River Basin, south-east Australia

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Freshwater molluscs are commonly found in archaeological sites around the world and can provide important insight into past human-animal-environment relationships through traditional zooarchaeological and western scientific methods as well as through the lens of Traditional Ecological Knowledge. While these taxa continue to play an important environmental, cultural, and economic role, many extant freshwater mollusc species are at-risk of extinction today, as over half of freshwater gastropod and bivalve species are assessed as either 'At Risk' or 'Data Deficient' by the International Union for Conservation of Nature (IUCN). More research is seen as essential to helping conservation efforts. In this way, the analysis of modern specimens when establishing proxy archives or strengthening zooarchaeological interpretations can not only benefit interpretations of the past but may also strengthen knowledge about the present status of species which can then have implications for the species' future survival.

This paper considers an ongoing research project investigating freshwater bivalve species *Alathyria jacksoni* on Ngintait and First People of the Millewa Mallee Country in the Central Murray River Basin in south-east Australia. This species is assessed as 'Data Deficient' by the IUCN, and the state of the population in the study area is currently not well understood as the last major study of the species was completed 40 years ago. While the current research primarily aims to investigate *A. jacksoni* as a paleoenvironmental proxy archive for the region, ongoing collaborations between university researchers and the First People of the Millewa-Mallee Aboriginal Corporation has revealed the potential benefit of this research for understanding the present state of the species and, therefore, helping in any future protection efforts. The main methods used in this research have been the regular monitoring and collection of species during field work activity as part of a modern calibration study, and the application of sclerochronology to modern specimens, where analysis of the growth and corresponding geochemistry of the molluscs' shell can be related to the ambient environment and biological events. The cross-disciplinary implications of similar research should be considered.

Preserving archaeological landscape to lower soil erosion risk in mountainous areas: a modelling approach

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Land degradation is a critical environmental issue worldwide. The latest projections on climate change indicate that increasingly severe storm intensity and runoff will induce greater soil losses by water erosion in the future than in the past decades. The 'FAO Global Symposium on Soil Erosion' noted that pre-industrial farming practices often contributed to maintaining healthy soils while modern intensive agriculture and mechanisation have frequently induced significant erosion. Archaeological sciences can contribute by exploring social and environmental interactions to examine the impact of different practices over long periods of time and considering what made different practices sustainable or unsustainable in terms of past soil management.

Historic Landscape Characterisation (HLC) uses a qualitative but formalised method to map historic landscapes' chronological and spatial complexity. Meanwhile, in environmental studies, the diachronic land-use-land cover (LULC) analysis has helped illustrate how different anthropogenic activities have altered the soil erosion rate in specific areas. Modelling can provide a quantitative and consistent approach to estimating soil erosion under a wide range of conditions. GIS integration with the RUSLE (Revisited Universal Soil Loss Equation) model has been applied to estimate soil loss at a regional scale. In previous HLC studies, LULC has been evaluated from the perspective of cultural heritage. In contrast, soil erosion modellers have used it as a proxy to estimate the soil erosion of an area.

In this study, HLC data were integrated in the RUSLE equation with the programming language R to evaluate the impact of archaeological landscape changes on contemporary environmental settings. This methodology has been tested through a case study in the Tuscan-Emilian Apennines (N Italy), an area particularly susceptible to landslide hazard. The study offers a new protocol that could be used by policymakers and stakeholders who need to develop strategies which encompass both natural and cultural values for landscape planning and management.

Into the Wild: reconsidering relationships between wilderness, re-wilding and archaeology

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This paper explores the entangled relationships between rewilding, wilderness and the historic environment and the role that archaeology can play in rewilding initiatives. Rewilding is a term used to describe an array of global conservation and land management approaches that aim to restore ecosystem function and increase sustainability of biodiversity, ecosystems and landscapes. Re-wilding is both a captivating and controversial concept that attempts to address ecological degradation; however, its archaeological implications have not been well discussed so far.

As rewilding practice grows in popularity globally, there are concerns of the effects of rewilding on the historic landscape and its potential to ignore indigenous histories and traditional ecological knowledge. On a practical level, there is limited guidance for how rewilding initiatives can sensitively engage with the historic environment, yet rewilding initiatives have the potential to destroy cultural assets and change the historic character of a landscape. Moreover, human relationships with 'wilderness' and where we place ourselves within our conceived construct of 'nature', has shaped ecological and conservation thinking since the Enlightenment. These concepts make it difficult to reconcile the long history of human-environment interactions, living entangled lives with 'nature'. Indigenous peoples and many Eastern cultures have long understood that humans cannot be separated from 'nature'. These core beliefs are deeply entangled with Western Romanticism, national identity, and patriarchal colonialism, with 'Nature' often presented a-historically and removed from context. Wilderness, then, creates a problematic relationship for rewilding, which can fail to recognise cultural and historical contexts.

At the same time, we believe that archaeological and palaeoecological records also offer important insights for nature conservation and restoration initiatives, including rewilding. Archaeology, with its deep time perspectives, can help to demonstrate how our current, and future, environment is the result of human activity over millennia. This long-term lens can prepare people for the notion that places, landscapes, and ecosystems change and indicate how ecosystems might adapt to these challenges over time. We examine these issues from a philosophical and practical stand-point drawing upon case study examples (e.g. from Bere Regis, Dorset and Drumadoon Estate, Arran).

An accurate age-depth model for the long sedimentary record from Lake Chalco, Central Mexico: implications for volcanology, palaeoclimatology and palaeolimnology

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Lake Chalco is an endorheic lake on the SE edge of Mexico City. Several drilling campaigns have taken place over recent years to address various scientific questions, including palaeoclimatic, palaeoenvironmental and volcanological reconstructions. In 2016, a drilling project funded by the International Continental Scientific Drilling Program (ICDP) focused on recovering the full lacustrine sequence at Lake Chalco, reaching a depth of c.550 composite meters below-the-surface (m_c). Due to the large number of active monogenetic and polygenetic arc volcanoes surrounding Mexico City, c.60% of the core is comprised of volcanically-derived deposits. The Chalco Sequence has been sub-divided into three stages, best reflecting changes in depositional processes and environments: (1) Stage I, Lava-dominated section, 448.86 – 553.93 m_c; (2) Stage II, Pre-lacustrine section, 293.71 - 448.86 m_c; (3) Stage III, Lacustrine-dominated section, 0 – 293.71 m_c. Stages I, II and III are interpreted to respectively comprise a succession of lavas, a primary volcanic collapse deposit and successive laharic deposits, and lacustrine sediments intercalated with laharic and tephra fall deposits.
To better understand the record at Chalco, an accurate age-depth model is crucial. From the 2016 cores, we have directly dated 12 samples by $^{40}Ar/^{39}Ar$ techniques, including 8 tephras (Stage III) and 3 lavas (Stages II and I). The age-model is further refined using tephrochronology, where we have been able to geochemically correlate fingerprinted tephras from the Xaltipan Ignimbrite eruption at Los Humeros caldera, Mexico and the Los Chocoyos (LCY) eruption from Lake Atitlan caldera, Guatemala, at 75 ± 2 ka and 164 ± 4.3 ka, respectively. We present a Bayesian-based age-depth model that accounts for these tephra ages, newly acquired ^{14}C ages for the upper c.50 ka, and fluctuations in sedimentation rate at lithostratigraphic contacts.
Our results reveal that the lavas at the base of the core erupted c.1.4 Ma, and the lacustrine sediments in the basin started to accumulate at c.450 ka. Since c.450 ka, at least 450 explosive eruptions have produced visible tephra layers within Lake Chalco and 13 Marine Isotope Stages (MIS) stages are recorded. This age-depth model permits detailed climatic investigations throughout these MIS stages for Central Mexico.

Unraveling the interactions between the Late Pleistocene megamammals and the earliest humans of the Pampas using stable isotopes

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The Pampas of Argentina is one of the regions with the earliest evidence of human occupation in South America. Well-dated archaeological contexts as early as ~ 14.5 ky cal. BP imply at least 3.000 years of coexistence and possible interactions with the Late Pleistocene mega mammals. Previous archaeological studies on megafauna focused on two main issues: i) the impact of humans on the megafauna extinctions; and, ii) the importance of these large body-sized mammals in the subsistence of the first human groups of the region. Recently, it has been proposed that the arrival and expansion of human populations influenced the extinction of the megafauna during the latest Pleistocene. The human-driven extinction of mega mammals could have prompted an interruption in the hunter-gatherer population growth and a trophic niche shift. Nevertheless, there is a gap of about 2000 years between the oldest cultural and the oldest human skeletal remains in Pampas, and the evidence of anthropic exploitation of mega mammals is elusive. There is no evidence for the assumption of a specialized niche of mega mammal hunters, therefore it is important to evaluate the paleoecology of the Pleistocene mammal community of the Pampas. In this sense, we are focusing on building an extensive stable isotope database of well-dated samples for the last glacial-interglacial period ~ 17-8.4 ky cal. AP of the Pampas, to evaluate the structure of such a community and their response to climatic or anthropic drivers before their extinction. Here we present the first systematic reconstruction of the isotopic niche of several mega mammal species, evaluate their paleoecology, and infer possible interaction levels, from scavenging to secondary exploitation or even hunting. We measured the carbon, oxygen, and/or nitrogen isotope values on bone/tooth apatite and bone collagen of several fossil species, not only that few ones present in the archaeological contexts. We include more than fifteen herbivorous species as well as the largest felid of the Pampas, the sabretooth cat Smilodon populator, and the gigantic carnivore-omnivore short-faced bear Arctotherium tarijense.

Forensic archeoseismology: using disturbed and liquefied earthquake graves to unravel past seismic events

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The ancient Roman city of *Complutum* (Alcalá de Henares, Madrid) was founded in the 1st century AD and it was one of the most important cities of Hispania. The old Roman city was partially destroyed and abruptly abandoned during the late 4th century AD by an earthquake. The new Roman city was relocated and rebuilt in a close settlement. In this work we show different Earthquake Archaeological Effects (EAEs) affecting the necropolis of *La Magdalena* site, an agricultural holding located 4 km away from the urban center of *Complutum*. The occurrence of a seismic event in the zone with a size ranging 5.0 – 6.6 Mw, according with the maximum surface rupture length of the Henares Fault, exceeded the minimum empirical limit of seismically-induced liquefaction. The main recognized EAEs are liquefactions (sand dikes and sand-gravel explosive craters), affecting Roman buildings such as water tanks (cisterns), houses and buried roman graves. Ground liquefaction generated significant soil cracks, explosive craters and folds in the foundations of the buildings. Ground liquefaction was apparently massive and affected several graves triggering significant displacements and dislocations in the bones of the buried skeletons. This allows us to obtain a radiometric age of the deformation by dating the disturbed carcasses within the graves. AMS ^{14}C dating to five well-preserved teeth throw consistent calibrated (2σ) ages of 240 – 360 cal BP. These dates place the deformation event between the late 3rd and the first half of the 4th centuries CE, which is consistent with archaeological dating by means of burial-related pottery, coins and the style of burial (coffins). The combination or radiocarbon data, archaeological information and *"post-mortem"* forensic evidence, make possible to locate the recorded event during the first half of the 4th century CE. The cadavers need some tens of years to decompose and allow free movement of the bones within the coffins.
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Poster - sessions 20, 25, 28, 37, 64, 72, 79, 82, 87, 104, 106, 142, 152, 158, 166, 174, 190

Dynamical modelling of subglacial meltwater erosion during past and future glaciations

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A large portion of meltwater from ice sheets and glaciers drains along the ice-bed interface, influencing the ice-flow dynamics. It is known from the geological record and modern glacial systems that channelized subglacial drainage generates high erosion rates and can form overdeepenings and tunnel valleys. We use the geological record and numerical modelling to quantify the meltwater-driven erosive potential during future glaciations in northern Germany. To achieve this goal, we develop and deploy a next-generation dynamical model for subglacial meltwater erosion on soft beds.

First, we build a 3D subsurface model of northern Germany to facilitate the reconstruction of ice sheet and subglacial topography during past glaciations. The subsurface model is based on the depth maps of the Geotectonic Atlas of North-western Germany, geophysical data and borehole data (GTA3D, TUNB3D-NI). Subsequently, the sedimentary units and hydrogeological properties are integrated into a geological grid model. The subsurface model will allow us to tune numerical hydrology and erosion simulations with linked drainage systems consisting of distributed and channelized components.

The hydraulic model is based on the principles of subglacial channel formation and fluvial erosion and is parameterized against tunnel valley formation during past glaciations. This model framework will be the first to use realistic sediment mechanics and 3D geological geometries to assess subglacial channel stability, evolution, and erosion. It will be used to estimate meltwater-driven erosion and sediment transport during future glaciations, with special emphasis on quantifying the north-to-south distribution of the maximum depth of meltwater erosion and associated environmental challenges in northern Germany. A particular focus will be on scrutinizing a proposed critical erosion depth of 600-800 m, which is relevant for planning repository sites for high-level radioactive waste.

Evolving bed roughness below Finnish ice streams resting on hard crystalline beds; the key role of overridden proglacial sediment in mineral exploration.

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Processes operating below modern and ancient ice streams are not well understood but are key to landform development, bed roughness and initiation and deceleration of streaming, and the response of the ice stream to climate and other variables. High resolution airborne LiDAR datasets are being employed by the Geological Survey of Finland (GTK) as part of a new national geological initiative (Glacial Features Database) to rapidly and cost-effectively map glacial landforms and sediments left by the last (Late Weichselian) Fennoscandian Ice Sheet on 'hard' crystalline rocks of the Fennoscandian Shield, 'soft beds' of overridden pre-existing sediment, and 'mixed' beds. This information is needed to inform mineral exploration projects by identifying beds composed of secondary recycled sediment from those resulting from primary subglacial erosion of bedrock. This presentation highlights information acquired from LiDAR, ground penetrating radar and outcrop data, and mapping of bed roughness by machine learning techniques, that identify changing bed roughness under ice stream in the Finnish Lake District that advanced to the Salpausselkä moraine system of Southern Finland during the Younger Dryas after 12,250 years before present. Ice streams advanced into shallow water of the Baltic Ice Lake flowing across an underlying soft bed composed of thick proglacial subaqueously-deposited fan-delta sediments and antecedent till that blanketed the underlying rough Shield surface. The soft bed was streamlined into drumlins and megascale glacial lineations by subglacial erosion to reduce basal drag; outcrop and many tens of kilometres of ground penetrating data show a thin till cap which functioned as an erodent layer which streamlined the underling soft bed. Continued subglacial stripping exposed large areas of hard mineral-bearing bedrock to erosion, producing dispersal trains of mineralized till, thereby increasing bed roughness, and contributing to deceleration of ice streams.

Erosional bedforms on hard beds in mid-continent North America cut by palaeo- ice streams of the Laurentide Ice Sheet

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We evaluate the origins(s) of regionally extensive glacially scoured and megagrooved bedrock surfaces on the hard bed of the Great Lakes sector of the Laurentide Ice Sheet in mid-continent North America, using newly available high resolution LiDAR derived data. These surfaces occur on a range of bedrock lithologies from Precambrian crystalline strata of the Canadian Shield, together with offlapping Paleozoic shales and limestone escarpments and plains in Canada and the northern United States. Surfaces show a wide variety of streamlined bedrock morphotypes ranging from large km-scale rock drumlins and linear mega-grooves to 'tadpole' and cigar-shaped spindles and more sinuous grooves, including sichelwannen and muschelbruch. We discuss the formative processes acting to cut these forms, focusing on the relative roles of sediment carried by high pressure subglacial water, direct glacial abrasion by basal debris, and the abrasive action of a 'third layer' of overpressured sediment moving between ice and its bed and acting as an erodent layer. We highlight the regional geological and paleoglaciological context of scoured bedrock surfaces and are able to recognize the critical roles played by enhanced erosion below fast flowing palaeo-ice streams, and varying bedrock lithology. This study emphasizes the fundamental importance of 'tectonic predesign' where Precambrian terrane boundaries, faults and fractures, extending under offlapping sedimentary strata, control the paths of palaeo-ice streams, deep erosion of the Huron-Erie-Ontario Great Lake basins and the other large lake basins around the margins of the Canadian Shield.

Tunnel valleys in the southeastern North Sea: Complex incision patterns dating back to MIS16?

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Large Pleistocene ice sheets have produced glacial structures both at and below the surface in northern Europe. Some of the largest and most erosive structures are so-called tunnel valleys. Here, we present the distribution of tunnel valleys in the southeastern North Sea between Amrum and Heligoland based on a very dense grid of high-resolution 2D multi-channel seismic reflection data (400 m line spacing). Using newly acquired data, the known tunnel valleys in that area can now be traced in greater detail and further westwards, which results in an increased resolution and coverage of their distribution. Additionally, we were able to identify an even deeper and older tunnel valley, whose orientation parallels the thrust direction of the Heligoland Glacitectonic Complex (HGC). This observation implies a formation before the HGC during an early- or pre-Elsterian ice advance (MIS16?). For the first time, we acquired high-resolution seismic profiles precisely along the thalweg of known tunnel valleys. These along-profiles offer clear indications for an incision during high-pressure bank-full conditions. The fill indicates sedimentation in an early high-energy environment for the lower part and a subsequent low-energy environment for the upper part. Our results demonstrate that a very dense profile spacing is required to decipher the complex incisions of tunnel valleys during multiple ice advances in a specific region. We also demonstrate that the time- and cost-effective acquisition of high-resolution 2D seismic reflection data holds the potential to further our understanding of the distribution, complexity and incision depths of tunnel valleys in different geological settings.

Discriminating tills of mixed provenance in central Canada to decipher the influence of two major ice dispersal centres of the Laurentide Ice Sheet

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The Hudson Bay Lowland (HBL) region of central Canada contains thick sequences (up to 65 m) of tills and intertill sediments deposited over multiple glacial-interglacial cycles. The notion of laterally continuous till beds is disproved by recent stratigraphic work that instead documents a fragmented stratigraphy that makes most correlations highly uncertain. The HBL glacial sediments also show evidence of mixed provenance. This is due to spatiotemporal variability in both the strength of different ice domes and the subglacial processes, which caused subglacial sediments of different provenance to be deposited and subsequently preserved or partially re-entrained and mixed in places, and covered or replaced by newly-produced sediments elsewhere. This study first uses multivariate statistics (e.g. PCA, k-means clustering, LDA) to determine if tills can be differentiated based on their till-matrix geochemistry and clast-lithology counts. These till-provenance parameters are then compared to the field-based till stratigraphy, across multiple study areas, to assess the compositional heterogeneity of stratigraphic beds. The degree of compositional inheritance/overprinting needs to be evaluated when attempting to identify till units by composition, as there may not be a clear relationship to a single ice-flow direction and provenance region. More broadly, this will add essential constraints to ice sheet reconstructions that currently only integrates information from till stratigraphy in a very limited way.

Late Paleozoic glaciated landscape in northern Africa as an outstandingly well-preserved analogue to Quaternary deglaciated areas

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The Ennedi sandstone plateau in Chad in north-central Africa exposes an outstanding example of an ice stream paleo-landscape that is of Paleozoic age. This assemblage of paleo-glacial structures is of comparable quality to that found in Quaternary deglaciated landscapes. A wide range of exceptionally well-preserved proglacial, ice-marginal and subglacial features are visible due to the absence of vegetation in the desert environment. Paleo-ice stream pathways contain swarms of large-scale glacial lineations distributed over the whole plateau that tell the story of a dying ice sheet during the late Paleozoic. A putative grounding zone wedge within a paleo-ice stream pathway allows the position of the former coastline to be reconstructed as it is assumed that ice streams terminated into a former ocean basin. Based on the convex topography and its position orthogonal to the large-scale glacial lineations, we present the first geomorphological interpretation of a grounding zone wedge in the Paleozoic record. Additionally, a unique system of inverted channel sediments in close proximity to glacial structures might record different phases of meltwater release during ice retreat. In summary, the Ennedi paleo-glacial landscape provides an excellent natural laboratory to understand the spatial relationship between subglacial, ice-marginal and proglacial components of a former ice sheet, with emphasis on exceptional outcrop quality that can be used to further our understanding of some Quaternary glaciated landscapes.

Anatomy of a sandy soft-sediment ice stream bed

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Links between ice sheet flow instabilities and processes operating at the ice bed are complex, non-uniform, and still not fully resolved. Detailed geomorphological studies of Quaternary palaeo-ice stream beds have driven major advances in our understanding of both hard- and soft-bedded ice-stream landsystems. Here we adopt techniques pioneered in Quaternary research and apply them to palaeo-ice stream beds of the Late Palaeozoic (~300 million years old), which represent an under-explored sandy end member in models of ice stream-bed interaction. We use a combination of drone-based and ground-based structure-from-motion photogrammetry to investigate the anatomy of a sandy, soft-sediment palaeo-ice stream bed at Oorlogskloof, Northern Cape, South Africa. Bedforms with a variety of morphometric characteristics were observed, including decimetre-scale sharp-crested flutes, centimetre-scale soft-sediment striated surfaces, horn-shaped transverse ridges, and tapered drumlinoid features. Analysis of aerial imagery revealed the variable distribution of these landforms across the preserved ice-stream bed, attesting to a complex spatial and temporal mosaic of areas of slip or stick. Here we quantify the morphometry of sandy sub-ice stream bedforms for comparison with their more widely studied heterogeneous counterparts, enabling us to test the influence of substrate composition on mechanisms of landform formation, subglacial drainage processes, and the nature of ice-bed coupling, with key implications for if and how substrate composition may influence flow instabilities such as streaming.

What can microtomography and micromorphology reveal about subglacial flute genesis?

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Debates continue on the formation mechanisms of streamlined subglacial bedforms such as flutes, drumlins, and mega-scale glacial lineations, and whether bedforms within and across these morphometric classifications have shared or variable genetic origins. A challenge facing exploration in contemporary settings is the lack of direct access to ice sheet beds. To overcome this challenge, we interrogate the fossilized remains of Late Palaeozoic ice sheets beds at Oorlogskloof, Northern Cape, South Africa. The Late Palaeozoic Ice Age (LPIA, ~360-260 Ma) is of particular interest as it represents the last time Earth transitioned from an icehouse to greenhouse climate; a warm end-member analogue for today's climate where glaciers and ice sheets are rapidly receding. Much like today, fast flowing ice streams drained continent-scale LPIA ice sheets, yet unlike the majority of well-studied Quaternary ice stream beds those of the Late Palaeozoic are unusually sandy. Here we demonstrate the value in combining 3D X-ray microtomography and 2D thin section micromorphology to dissect the internal structure, composition, and polyphase genetic history of sand-rich streamlined bedforms. This study offers insight into the basal processes operating at sandy soft-bedded ice streams, which holds broader implications for how glaciers and ice sheets may slip or stick over soft-sediment beds in ancient, Quaternary, and contemporary settings.

Quaternary Deposits in Northern Switzerland: correlation between facies distribution and paleo-topography

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In order to develop and implement safe and sustainable long-term solution for the disposal of radioactive waste in Switzerland, Nagra cooperative is carrying out research for a repository site in line with the so-called "Sectoral Plan for Deep Geological Repositories" under the leadership of the Swiss Federal Office of Energy (SFOE).

The key decisive factor in determining the safety of a repository site is the stability of the underground conditions. Understanding and characterizing the subsurface is therefore the fundamental step in the site selection process. One of these criteria relates to future erosion and its importance for the long-term safety and long-term stability of a repository. For this purpose, several factors are considered, one of those is the erosion resistance of the overlying rock and the topography. Changes in topography over the last approximately two million years are used to derive various future developments in erosion for the area of interest in Northern Switzerland.

Starting from an eleven boreholes dataset from N Switzerland positioned in different morphological glacial settings (overdeepened glacial troughs, fluvial paleochannels, etc) Quaternary deposits have been systematically and consistently logged according to lithology and depositional environments.

Core data attributes (grain sizes, thicknesses, lithology and environmental facies) have been compared to the reconstructed Quaternary basemap reconstructed integrating regional well and 2D/3D seismic data, made available by Nagra. The well data have been overlapped on few available 2D seismic sections to trace correlations and reconstruct the filling deposits stratigraphy of the examined incised valleys.

The aim of this paper is to show how correlation trends can be successfully displayed using an integrated approach where Quaternary sediment characteristics can be quickly interrogated and compared against key controlling factors like Quaternary morphology and depositional environment. Such more regional trends are fundamental when predicting Quaternary sediment properties (velocity analysis and model for depth conversion, static models...) away from well control points.

Subglacial upper-flow-regime bedforms in a murtoo, Holocene SW Finland

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Compared to the efficient channelised meltwater flow associated with ice marginal eskers and proglacial environments we know little of meltwater flow in inefficient distributed systems beneath ice sheets. Previous studies have indicated the overall common presence of upper-flow-regime bedforms in glacigenic settings. However, facies expressions of subglacial density flows remain poorly documented. We excavated three ca. 3 m deep and up to 70 m long trenches across a murtoo-landform in a late-glacial to Holocene meltwater route in SW Finland. These excavations provide a detailed window into sediment structures presumably formed ca. 40-50 km from the coeval subaqueous margin of the Fennoscandian Ice Sheet (FIS). The aim of this study is to document small-scale density flow sediment structures of silty to gravelly lithologies, which characterize the proximal and central parts of the studied murtoo during its early evolutionary phase. Seven main facies types dominate the interval: current ripples and silt drapes; parallel lamination; sinusoidal lamination; sigmoidal cross-lamination and -bedding; scours with backsets; scours with structureless pebbly sand; and poorly-sorted gravel lenses. The facies commonly form compound bedforms on the concave-convex topography and are interpreted to include various upper-flow-regime bedforms. Our results confirm that meltwater processes play a critical role in murtoo deposition. Overall, the findings contribute to understanding of semi-distributed subglacial meltwater systems during the retreat of a continental ice sheet (FIS) in a rapidly warming climate.

Reconstructing LGM Rhine glacier ice-flow patterns based on subglacial landforms

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We present a comprehensive inventory of subglacial landforms in the footprint of the LGM Rhine piedmont glacier, one of the largest glacier systems of the Alpine LGM ice cap. In a second step, we use orientation and morphometry of streamlined bedforms to deduce paleo ice-flow patterns thereby providing new insights into the dynamics of the Rhine glacier during the LGM. On the basis of high-resolution elevation data, we mapped ice-marginal moraines and more than 2500 subglacial landforms. Two main moraine complexes dominate: the Schaffhausen stadial moraines which document the maximum extent and the Stein am Rhein stadial moraines (Kamleitner et al. submitted). Our subglacial landform dataset is comprised predominantly of drumlins, but also includes glacial lineations and subglacial ribs (Rogen). Drumlins occur mainly in fields internal to the frontal moraines of the Stein am Rhein stadial. We interpret these as a coherent flow set that formed isochronously during the late LGM readvance to and the active stabilization at the Stein am Rhein ice margin. True readvance is documented by sedimentological evidence at several sites (Schreiner, 1992). Deviating bedform orientations in the flow set, like cross-cutting relationships or superimpositions are rare. Mapped bedform orientations of this flow set provide the basis for reconstructing basal ice-flow patterns during the Stein am Rhein stadial. We used a new kriging approach following Ng and Hughes (2019) to infer a continuous paleo flow field. The interpolated flow field demonstrates radial ice flow outwards from the mouth of Alpenrheintal as ice fanned out towards the frontal moraines. We see strong topographic control of basal ice flow during the Stein am Rhein readvance. Flow lines diverge due to deflection around topographic highs and converge in narrow valley sections. Combining gained flow lines with information on bedform elongation allows to delineate potential areas of relatively high basal velocities. These largely coincide with known overdeepenings. Geomorphological reconstructions are in accordance with predictions from numerical simulations that find highest sliding speed along Thur Valley, and in the Lake Constance and Lake Überlingen basins (Cohen et al., 2018).

Sardinia and Sicily: Two islands two worlds

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The endemic faunas of Sardinia and Sicily, the two central Mediterranean's largest islands, underwent highly diverse evolutionary histories due to the two islands' different palaeogeographic evolution during the Cenozoic. Sardinia, an oceanic-like island, after its separation from Iberia approximately 30 Ma ago, was part of the Tusco-Sardinian palaeoarchipelago during the Late Miocene and became a completely isolated insular district by the end of the Messinian. Since the early Pleistocene, good swimmer large mammals have entered Sardinia during major sea level lowering phases. These active dispersal events and the passive arrival of small mammals through natural rafting led to faunal turnovers that reduced the biodiversity of the mammalian fauna, with an exception given for the arrival of the ancestors of four otter species in the Late Pleistocene. Conversely, the biodiversity of Sicilian endemic fauna increased progressively during the Pleistocene as a result of marked changes in the extension power of the barrier that separated the island from southern Europe. The diverse structure and composition of the endemic faunal complexes indicate a strong geographic isolation in the early Middle-Late Pleistocene and the presence of temporarily emerged and discontinuous land strips connecting the island to Calabria by the Middle Pleistocene end.

The time and mode of the colonisation of large Mediterranean islands by Palaeolithic humans is an open and hotly disputed question. In Sardinia, remains of Anatomical Modern Humans (AMH) are recorded in the early Holocene, while the hypothesis of the presence of Middle Palaeolithic hominins during the Last Glacial Maximum (LGM), if not earlier, requires confirmation by sound evidence. In Sicily, available evidence indicates that AMH colonize the island during the LGM, when a land bridge emerged.

Results of recent research on the Marettimo island (Sicily), obtained by cross-referencing radiometric datings with palaeogeographic, palaeontological, and relative sea level change data, suggests that seafaring in the western Mediterranean area began between the early Mesolithic and late Epigravettian, though it probably became a well-established practice since the Neolithic.

Palaeogeographic and palaeontological data is critical for disentangling the evolutionary dynamics of insular fauna and resolving the contentious topic of island colonization by prehistoric humans.

Island ecosystem ecology from deep prehistory to the Anthropocene

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Humans are fragmenting ecosystems into habitat 'islands', causing an unprecedented global collapse of large mammal populations just as science is discovering their essential ecological roles. The impact of these losses is such that our understanding of the contemporary biosphere is clearly shaped by a world artificially depleted of terrestrial giants. However, the causes of megafaunal extinctions over a much deeper, >50,000-year timeframe, remain strongly contested. How did specific anthropogenic and/or climate factors interact to transform and collapse megafaunal ecosystems and what implications did this have for human societies at different points in time? The feedbacks and ecological legacies of these older extinctions have important lessons for the current biodiversity crisis, yet the dearth of good quality fossil and contextual data from many regions, settings and species has prevented robust appraisal.

The ERC ISLANDLAB project (PI. E. Scerri) will explore these questions using the Maltese Islands as a frame of reference for the effects of anthropogenic ecosystem fragmentation. Pilot work has already uncovered an unprecedented deep-time record of pristine natural systems successively interrupted by waves of humans, with evidence of direct interaction between humans and the endemic megafauna. Extinctions can be documented from deep prehistory to Europe's first monumental civilizations, with exponential losses and subsequent faunal reintroductions lasting until the mid-Holocene. By building high-resolution ecological, climatic, and archaeological characterisations of Malta before and after human arrival and subsequent alteration of biotas, ISLANDLAB will therefore document long-term legacies and feedbacks between ecological changes, societal responses, and ecosystem resilience. More broadly, the results will shed light on extinction processes in current anthropogenic landscapes, elucidating the ecological and human dimensions of restoration pathways from an island paradigm at a pivot between Europe and Africa.

The first and last appearance dates of the dwarf elephant Palaeoloxodon falconeri on Sicily, based on new dates from Spinagallo Cave

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We present new dates for the Sicilian dwarf elephant *Palaeoloxodon falconeri*, from its richest and most important fossil locality, Spinagallo Cave. At 1m-tall, *P. falconeri* is the smallest elephant ever to have lived and – descending from the 4m-tall, 10 ton *P. antiquus* – the most extreme example of insular body size change in mammals. *P. falconeri* epitomises the Island Rule, is the focus of evolutionary and palaeobiogeographical research, and is key to palaeogeographic and palaeoenvironmental reconstructions, as well as the regional biochronology, of Sicily and Malta – and yet we cannot answer basic questions concerning its evolution and ecology owing to a lack of robust chronology. Using uranium-thorium, optically stimulated luminescence, and electron spin resonance dating, we took a 'range-finding' approach to constrain the age of both historically-excavated *P. falconeri* fossils, and remnant *P. falconeri*-bearing sediments within Spinagallo Cave, to show that *P. falconeri* had evolved by 334ka, 200ka later than previously thought. *P. falconeri* was still present on Sicily at 258ka, and likely persisted beyond this date. Our new dates place the evolution and extinction of *P. falconeri* within the palaeogeographic and palaeoclimatic framework of MIS10 to MIS6, a time of low-amplitude sea level change that ensured persistent insularity with respect to the mainland for the Siculo-Maltese paleaoarchipelago, but where transitory connections between Sicilian palaeoislands were also possible. This reconciles the existing conflict between palaeogeographic reconstructions of *P. falconeri* evolving within a discontiguous archipelago, and the clear biogeographic signal for connectivity between north and southeastern Sicily (e.g. the presence of *P. falconeri* in both Northern and Hyblean regions).

Spatial Reconstruction of Hominin Environment in Java

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Homo erectus was firmly established in eastern Java a million years ago. A major portion of the Late and Middle Pleistocene fossil sites in Java is located in the eastern part of the island. To date, the palaeoenvironment of early hominins in Java has been studied for Sangiran and other sites, but the resulting environmental reconstructions are remain restricted to limited areas and only focused at one subject (i.e. palaeoenvironment, palaeoclimate, palaeogeography).

This study is the first step of a 'Living in Sangiran' project, focusing on analysing and testing the relationship between *Homo erectus* behaviour and environmental dynamics in Sangiran, Java. While functionally diagnostic find situations are absent for this early episode of settlements, such an approach allows the study of the preconditions, circumstances and effects of the relationships between human behaviour and environmental dynamics. In this study, we aim to develop a spatial reconstruction of the environmental and climatic conditions under which hominins lived based on present-day analogue, which polarized based on the palaeoenvironment and palaeoclimatic data available. A set of concerted maps on palaeogeography, palaeoclimate and palaeovegetaiton, based on each other, will provide spatial data on topography, coastlines, hydrology, rainfall patterns and plant cover for the eastern part of Java. The result of this study provides a more detailed, and for the first time, spatial sense of how the spectrum of available resources and their seasonal dynamics were distributed in the palaeolandscape of *Homo erectus* in the eastern part of Java.

The ArchaeoGLOBE Island Extinctions Project: Mediterranean Islands case study

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Humans have for millennia managed and transformed the environments they inhabited, impacting regional biodiversity, climate and landscape. The material record of human alterations of the globe is deep and heterogeneous with important social, cultural and technological differences across time and space. Despite an increasing interest in the relationship of humans with their environments, major gaps remain in our understanding of the temporal trajectory as well as the environmental consequences of human exploitation of the Earth. Of particular interest in this context is the impact of human interactions with island ecosystems. How human societies colonised and transformed biotas and ecosystems of pristine islands worldwide, and in turn how these new environmental settings have transformed those societies, is a topic of global scientific interest exemplified by the ArchaeoGLOBE project. The ArchaeoGLOBE Island Extinctions Project explores the expansion of modern humans into island environments globally to test theories about the causes of species extinctions and extirpations in these unique ecosystems. The Mediterranean forms the first case study of this major collaborative project as one of the better studied regions globally and one that highlights where important scientific and methodological gaps remain in the study of global human history. Here we present the results of our data synthesis of the archaeological, palaeontological and ecological record for Mediterranean islands, and discuss the ecological consequences of human expansion to the region's island clusters, in particular habitat transformation and biodiversity loss as a result of human settlement, while highlighting the methodological challenges for this scale of project.

Stratigraphy and chronology of Pleistocene cave sediments and faunal remains from Għar Dalam, Malta

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Għar Dalam, a cave site located in south-east Malta, is renowned for its late Pleistocene faunal assemblage. Amongst other species, numerous fossils of elephant, hippopotamus and deer have been recovered from the site, including several dwarf species. These were discovered during a long series of excavations in the late 19th and early 20th century led by researchers including Cooke, Despott, Caton Thompson, and Baldacchino. However, these deposits previously lacked sufficient chronological and stratigraphical control to definitively declare when these species were present on the island. This is a critical barrier to studies concerning the evolution of Malta's insular fauna and the role that climate fluctuations and sea-level change would have played.
To provide improved chronological constraint, a comprehensive suite of U-Th analyses have been performed on carefully selected in-situ speleothems (stalagmites, stalactites, flowstones) found in association with the cave's fossil-bearing stratigraphy. Based on the U-Th ages, we consider the earliest deposits - a bone breccia/conglomerate containing elephant, hippopotamus and deer - to pre-date 165.90 ka, indicating that these species existed on Malta during or prior to MIS 6d and before the penultimate glacial maximum. Overlying red earth deposits dating to between 167.27 ka and 151.19 ka (MIS 6c or 6b) also contain the same faunal species. Significant speleothem formation between c.152 ka and c.134 ka corresponds with the penultimate glacial maximum and suggests a break in sedimentation occurred during the last interglacial. Red earth deposits post-dating this period show evidence of reworking, making it difficult to constrain the age of fauna recorded from these layers, or to correlate with other regions in the cave, hampering assessment of species persistence beyond Stage 6. However, in situ material present in the remaining deposits offer some clues: whilst deer did survive, it is not clear whether this indicates continued occupation by the same population, or a phase of extinction followed by re-population.

Rise and fall of wetland habitat and megafauna interaction in mid-latitude North America during the last deglaciation

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In a previous work, we discussed multiple lines of evidence that suggest extensive wetland development in the American Midwest during the Bølling-Allerød (B-A). The Laurentide Ice Sheet meltwater was flowing southward through the Midwest before it was diverted to the northern fluvial routes close to the onset of Younger Dryas (YD) cold period. The combination of meltwater, remnant ice blocks, and increased precipitation potential provided water sources for the B-A wetland expansion across generally flat landforms of the Midwest. We showed that the B-A wetland expansion provided explanations on the overall vegetation openness as well as the temporal dynamics of major no-analog pollen taxa. For example, anomalously high *Fraxinus* pollen percentages during the B-A were indicative of widespread swamp forests with remaining areas flooded by meltwater rivers. The YD was followed by high abundance of *Larix* pollen that can tolerate cold conditions, and poor soil environments. Additionally, other available case studies support the presence of local wetland-like habitats for certain megafauna species. In this study, we expand on this idea of deglacial wetlands being last habitats for wetland-adapted megafauna species. Data were primarily obtained from two open-source databases, the Paleobiology Database (paleobiodb.org) and the Neotoma Paleoecology Database (www.neotomadb.org). Preliminary analysis of vertebrate faunal localities suggests major overlaps of fossil distribution and timing of three megafauna species known to have foraged in wetland environments, *Castoroides ohioensis* (Giant beaver), *Mammut Americanum* (American mastodon), and *Cervalces scotti* (Stag-mosse), with our earlier reconstruction of area grid cells for the B-A wetlands. With diminishing meltwater supply into the YD period, the wetland habitats were largely lost, supporting the idea that habitat loss may have contributed to end-Pleistocene megafauna extinctions. We also explore the recent paradigm of emphasizing active roles of megafauna on ecosystem evolution by further discussing that (1) those large animals were actively pursued and inhabited in the B-A wetlands and may have contributed to the observed increases in mid-latitude methane sources at this time period; and (2) their activities had lasting effects on the soil biogeochemistry that supported the following YD expansion of open *Larix* peatlands.

Sensitivity of varve biogenic component to climate in five Finnish lakes

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Varved lake sediments provide a unique opportunity to examine the relationship of climate and lakes as well as lake catchments. Indeed, varve total thickness and clastic component thickness have been broadly used to study changes in past climate. In addition, varve biogenic component can form a notable part of varve total thickness and seasonal variations can influence the amount of deposited biogenic matter. However, the number of studies that discuss the varve biogenic component or its thickness is limited.

We investigated recent (100-year) varve records of five Finnish lakes with different catchments. The thickness of varve biogenic component and its sensitivity to growing season temperature and open water season precipitation was examined. The statistical analyses between varve biogenic component thickness and climate parameters confirm that the varve biogenic component thickness in the studied lakes is sensitive to the studied climate variables.

Lakes with high trophic status show positive correlation between varve biogenic component thickness and growing season temperature. For lakes with positive correlation between varve biogenic component and precipitation, the catchment soil type seems to be the factor behind the positive correlation. These findings indicate that warm summers and high precipitation lead to enhanced varve biogenic component thickness. Warm summers intensify primary production and higher precipitation enhances transportation of allochthonous biogenic material, both factors generally leading to thicker varve biogenic component. However, two of the studied lakes show more complex relation to climate. For instance, lake trophic status and abundance of coarse-grained material in the catchment seem to affect the correlations. Despite numerous human actions in the catchments of the studied lakes, the climate signal on varve biogenic lamina thickness, interestingly, is still detectable. Thus, this study reveals that varve biogenic component thickness has high potential for climate reconstructions.

MAGIC - MArgaritifera' shell : Geochemical Investigation of their Concretion to reconstruct past environment's variations.

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The fresh water mussel *Margaritifera margaritifera* can be found in different hydrosystems around the world. Its capacity to create pearls, together with its environmental specificities (umbrella species), made it an endangered and protected species. Previous geochemical studies on their shells had revealed its potential to record (and reconstruct) past physical parameters of the river, such as temperature. Microscopic analysis of yearly increments is also used to create a precise schlerochronology. Both features make it a potential robust paleothermometer archive.

This study aims at comparing schlerochronology with geochemical analysis of trace metal elements and stable isotope ratios ($d^{18}O$) performed on multiple mussel's shells from the Dronne River, located in South-West of France. Using a valuable paleothermometer's equation for carbonates (Epstein et al., 1953), together with reconstruction of the $d^{18}O$ signal of the river using nearby record of precipitation's $d^{18}O$ measured nearby between 1998 and 2012 (Genty et al., 2014), this study proposes a quantitative reconstruction of the temperature evolution over the last 60 years. The general trend of the river temperature evolution, including seasonal variations, will be compared to other regional records, and confronted to regional forcings, such as the North Atlantic Oscillation (NAO), as well as global forcings.

Anthropocene response of diatom and chironomid communities to external inputs and climate change in high mountain lakes

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Mediterranean high mountain freshwater ecosystems are particularly sensitive ecosystems to global change. Long-term sediment records provide cumulative paleo records of communities across the lake and their responses and changes over time. The main aim of this study is to evaluate the Anthropocene nature and timing of changes in Mediterranean high elevation lakes based on different proxies and assess whether they are consistent with recent warming. A sediment core was taken in Borreguil Lake (at an elevation of ~2800m a.s.l. in Sierra Nevada National Park) from the deepest area of the lake using a slide-hammer gravity corer and was extruded on-site with a high temporal resolution (intervals of 0.25 cm). The core was dated using ^{210}Pb, ^{226}Ra and ^{137}Cs by direct gamma assay establishing a chronology for the past ~150 years. Samples were processed and analyzed for diatoms, chironomids and algal group marker pigments. For each sample, a minimum of 300 valves and 50 head capsules were counted for diatoms and chironomids, respectively. Pigments were analyzed using liquid chromatography (UHPLC). Diatom assemblages were dominated by small benthic fragilarioid taxa such as *Pseudostaurosira brevistriata* as well as other taxa like *Achnanthidium minutissimum*, *Gomphonema* and *Pinnularia* species. The greatest compositional changes identified occurred during the 1960–80s and are indicative of alkalinization of the lake and an increased aridity since the 1960s. Chironomid assemblages showed a low taxonomic richness, consistent with an oligotrophic alpine lake, and with high abundances[OH1] of *Psectrocladius sordellus*-type and *Coryneura arctica*-type. Pigment analysis highlights a significant increase in the lake primary producers biomass from the year ~1700 onwards. Around 1970 there was a major shift and primary production moved from the bottom benthic zone indicated by diatom diatoxanthin (more transparent lake) to the pelagic zone with a greater contribution from cryptophytes (alloxanthin) growing at depth and chlorophyceae or green algae (lutein and zeaxanthin) growing in the pelagic zone. Thus, our results are indicative of significant changes in the lakes and their catchments along the Anthropocene that accelerated in the 1960s–1970s, concurrent with trends in rising regional air temperature and declining precipitation.

Between climate and anthropogenic forcing: Holocene paleoenvironmental evolution of the Somme valley peat sequences (Northern France)

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The fluviogenic peat (fen) are fragile environments that provide outstanding archives to describe environmental evolution. At the scale of northwestern Europe, the valley bottoms of the River Somme basin make remarkable wetlands characterized by a significant fluviogenic peat accumulation (5 meters on average) mainly over the last 12,000 years. The actual research has been initiated to highlight the respective roles of climatic and anthropogenic forcing factors (drainage, slope soil erosion) on peat formation/degradation processes and the modification of the related fluvial environments. This study is focused on a stratigraphic transect of 600 meters wide based on more than fifty manual boreholes and mechanical corings located in the large meanders of the Upper Somme Valley (Morcourt). The reconstruction of both sedimentation dynamics and palaeoenvironments evolution is based on a multiproxy approach combining sedimentology, geochemistry, palynology, and plant macro-remains identification, supplemented by thirty ^{14}C dates. This stratigraphic sequence reveals a first peaty event (14.6 - 14.0 ka cal. BP) preserved as small channel infillings during the Lateglacial period. Then peat formation restarted at the beginning of the Preboreal period around 12 ka cal. BP and rapidly extended to the entire valley bottom during the Boreal (0.07 cm/year). Until the Subboreal, typical peat (TOC values > 45%) continue to fill in the valley before a brutal reactivation of fluvial dynamics in a deep single meandering channel (3.3 ka cal. BP); slows down of peat accumulation rates (0,03 cm/year). Around 2.9 ka cal. BP, at the Bronze Age, peat is enriched with calcareous silts (15 to 60%) resulting from topsoil erosion of the slopes. Despite increasing signs of anthropization (increase of cereals and ruderal plants pollens and decrease of tree pollens), peat formation restarts in the early Middle Ages, highlighted by the development of *Cladium Mariscus*. From 0.8 ka cal. BP, again the hydrological system was disturbed and the peat system definitely transformed into drained wet meadows buried by the deposition of clayey silts fed by soil erosion. The paleoenvironmental history, combined with climatic and anthropogenic forcing factors, provides keys to understanding the current ecosystem and possible restoration trajectories for valley bottom peats.

Reconstruction of landscape paleohydrology using the sediment archives of humic lakes – study from northeastern Poland

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Sediment layers of uniform age within lakes (isochrones) and their patterns reflect accumulation processes which can be correlated with hydrological conditions in lake basins. The sedimentary archives in three small humic lakes in northeastern Poland (Wigry National Park) were described based on the correlation of local pollen assemblage zones in cores that were collected from the centers and margins of each lake. Past regional groundwater levels could be discerned from the morphology of the isochrones. The concave configuration of the isochrones in the studied lakes shows that regional groundwater levels remained mostly high and stable throughout their history. However, no single, common water level fluctuation pattern was identified in the three water bodies. High water levels throughout the Holocene was noted only in Lake Ślepe while other lakes in the region experienced a fall in water levels during the Boreal period. Lower water tables were identified in the older part of the Subboreal period in Lake Suchar II, whereas in Lake Suchar Wielki, this decrease persisted over a longer period, from the Younger Dryas to the Subboreal period. There were clearly some different trends in water level fluctuations in the Wigry Park lakes in comparison to those in other lakes in the region. This suggests that the lakes were influenced by local hydrological factors, in additional to regional climate, such as the size of catchment, catchment/lake ratio, shape of the lake basins (high slopes), groundwater hydrology, and development of local stream networks.

Hydrogen isotopic signatures of algal lipids as a new proxy for the reconstruction of past phytoplankton ecological dynamics

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Phytoplankton community composition plays a key role for biogeochemical cycling of carbon, nitrogen, and phosphorus as well as maintaining water quality. Therefore, changes in algal ecology due to environmental alterations virtually affect all ecosystems. To investigate phytoplankton ecological dynamics in response to past environmental changes, paleolimnologists have frequently analyzed microscopic algal remains preserved in the sediment, e.g., diatom frustules or dinoflagellate cysts. However, most taxa, including green algae and cyanobacteria, do not produce siliceous/calcareous parts, limiting estimation of their past abundance. Here, we focus on developing a new multi-proxy approach to reconstruct past phytoplankton community. This work targets the lacustrine algal response to human impacts in central Switzerland in the 20th century, as well as long-term changes during the Holocene.

Previous culturing and mesocosm experiments have shown that the relative offset in hydrogen isotope ratios of different algal lipids ($\varepsilon_{\text{Lipid1-Lipid2}}$) strongly differs among different phytoplankton groups. For example, $\varepsilon_{\text{palmitic acid-phytol}}$ values for green algae and cyanobacteria were ~350‰, whereas other taxa showed a much smaller offset (~200‰). To validate these results in a natural system, we collected algal biomass samples from the water column of Rotsee, a small eutrophic lake in central Switzerland, every second week from 2019 to 2020. Phytoplankton cell counts were also conducted for each sampling date. Consistent with past culturing and mesocosm studies, $\delta^2H_{\text{palmitic acid}}$ values increase with greater relative biovolume of green algae and cyanobacteria. We further present calculations of $\varepsilon_{\text{Lipid1-Lipid2}}$ for different lipid pairs including phytol and sterols in relation to the biovolume of phytoplankton groups and pair these with lipid distributions to develop a new multi-variate framework for reconstructing past algal community composition.

Following up on this, we apply our approach to a ~14 m long sediment core from Rotsee collected in 2021 spanning the past 13 kyr. We present a preliminary reconstruction of phytoplankton community dynamics during different time periods by calculations of $\varepsilon_{\text{Lipid1-Lipid2}}$ as well as the lipid distribution in the sediment– in this context, we compare the magnitude of change in the algal community in response to 20th century anthropogenic impacts (i.e., eutrophication) to the natural variability throughout the Holocene.

Exploring the environmental signals recorded in Holocene calcite varves from Diss Mere, England using a modern limnological monitoring approach

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Diss Mere is a small natural lake located in the centre of the town Diss in Norfolk (England). The lake, which has been exposed to different stressors including climate variability and changing land use, has significant recreational, historical and environmental value. The Diss Mere sediments are annually-laminated for most of the Holocene (2.1 – 10.3 ka BP), which allows the study of the lake evolution and its response to past changing environmental conditions at an exceptionally high resolution. As with many mid-latitude, alkaline, eutrophic lakes, Diss Mere's sediments are formed of biogenic-calcite varves, resulting from the complex interactions between biological, chemical, and physical processes. We have conducted a 3.5-year lake monitoring survey including sediment trapping techniques to identify the main external drivers and seasonal processes contributing to lake sedimentation. Our results demonstrate that the modern lake is still forming seasonally-differentiated sediments today, suggesting varves are still forming in the present system. These varves however are unable to be preserved, likely due to the permanent oxygenation of the lake bottom resulting from the gradual lake shallowing. Seasonal sediment fluxes follow a general pattern of i) an early spring diatom bloom of predominantly *Stephanodiscus hantzschii* and *Cyclostephanos dubius;* ii) spring precipitation of medium-coarse endogenic calcite grains; iii) summer precipitation of smaller endogenic calcite grains; and iv) an autumn algal bloom, and endogenic calcite precipitation intermixed with benthic diatoms and micrite. Higher primary productivity occurs in autumn as a response to lake overturn, and nutrient recirculation and input to the photic zone. Whilst calcite precipitates throughout the whole year, peaks are observed in the epilimnion during the summer, followed by a secondary peak in autumn in the hypolimnion indicating either resuspension, biological-induced precipitation, or both. Seasonal lake sedimentation is driven by the annual mixing cycle of the lake, which is strongly influenced by air temperature and wind. This study shows that a modern analogue approach can be applied to the ancient varves revealing the potential for summer temperature reconstruction driving calcite precipitation, winter wind conditions enhancing larger diatom blooms and interannual climate variability through the Holocene.

Historic lake levels and paleoecological peatland and forested wetland extents driven by the same climatic changes, northern Alberta, 1394 to 1988 CE

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There is concern that ongoing global climate change in the boreal region will lead to lakes becoming shallower, and wetlands drying and becoming afforested. Historical and paleoecological records from Northern Alberta were evaluated to assess lake and vegetation responses to past climate changes.

Historical records of lake levels were obtained for four unregulated lakes in northern Alberta and southern Northwest Territories. Historical records of five climate variables and indices were obtained: mean annual temperature (MAT), total annual precipitation (TAP), summer PDSI, and indices of the Arctic Oscillation and Pacific Decadal Oscillation (PDO). Lake levels for the four lakes consistently exhibited positive Pearson correlations with TAP and PDSI and negative Pearson correlations with MAT, AO and PDO. Lake levels were thus shallower when conditions were warm and dry which tended to occur during positive phases of AO and PDO.

A fossil pollen and spore record was created from Ninisith Lake sediments at a continuous 2.5 mm resolution (n=96, range=1394 to 1988 CE). In 1988 CE the 1.0 ha lake was 3.2 meters deep and was surrounded by black spruce dominated wetlands which were in turn surrounded by peat wetlands. When smoothed using a lowess filter, pollen and spore records exhibit centennial scale patterns. Percentages and accumulation rates of Cyperaceae, aquatic pollen taxa and *Sphagnum* spores exhibit maxima in 1394, 1626, and 1856 CE, and minima in 1507, 1732, and 1919 CE. Percentages and accumulation rates of *Picea mariana* and *Pinus banksiana* pollen exhibit the inverse pattern of that for Cyperaceae, aquatic pollen taxa and *Sphagnum* spores.

Four annually resolved climate reconstructions were obtained and binned to the same years as the Ninisith Lake sediments: temperature, lake sediment $d^{18}O$, PDO and AO. Pearson correlations between the climatic reconstructions and the pollen and spore records indicate that warm temperatures, more negative $d^{18}O$ and high PDO correspond with forest closure and lake shallowing, while opposite climatic conditions led to forest opening and lake deepening.

Hydrological fluctuations and fires during the Holocene in the shadow of a changing climate and growing human impact in East European Plain based on the palaeoecological reconstruction of continental ombrotrophic bog

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The large continental ombrotrophic peatlands in Eastern Europe are a unique archive of high-quality information about past hydrological dynamics (including long-term droughts) and fire activity. Still, paleoecological reconstructions based on testate amoebae and charcoal analyses for the Holocene are poorly documented. It remains unclear how large ombrotrophic bogs in the continental zone responded to dry climatic phases and increased human impact in the past and how natural fires and human activity have influenced these landscapes in this part of Europe. Therefore, we analysed testate amoebae and charcoal from the peat core from Gorodetsky Moch bog, one of the large continental raised bogs in the East European Plain. The main objective is to investigate the relationship between fire activity, droughts and climate changes over the last 4200 years (in the Meghalayan stage) based on palaeoecological reconstruction. For this purpose, testate amoebae analysis was used to reconstruct long-term hydrological dynamics. Micro and macro-charcoal analysis was used to identify a record of fire activity in detail. These data will be supported by the time scale based on plant macrofossil samples 14C-dated in high resolution and possibly tephrochronology. Furthermore, we performed analyses of plant macrofossils, pollen, and loss on ignition (LOI). The research is carried out as a part of a PRELUDIUM project (2019/35/N/ST10/03492) financed by the National Science Center (Poland).

Lateglacial- Early Holocene carbon accumulation in a Pyrenean peat bog

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Peatlands cover approximately 3-4% of the Earth's land surface and store nearly 30% of soil carbon. Around 50 million hectares of peatland have been historically damaged; these areas contribute 4% of global human-induced greenhouse gas emissions annually. The best known carbon reservoirs developed in peatlands of northern latitudes during the Holocene. Less known are peatlands developed during post-glacial times, when CO_2 was lower and abrupt climate changes occurred, e.g. the Bölling/ Allerod (B/A) and the Younger Dryas (Y/D). We argue that extensive research of this pre-Holocene period would provide valuable information on how the rapid post-glacial climatic shifts influenced the pre-Holocene peatlands, mainly rates of change of carbon storage and hydric changes. Results would provide insights on the long-term evolution of peatlands and carbon accumulation without human influence. The present study focuses on peatland origin and evolution during pre-Holocene conditions and explores a record from a mountain peat bog (Southern Pyrenees). The Bassa Nera pond is located in a Pyrenean-protected area and the results obtained from this research are aimed at supporting conservation practices in front of global warming. The main goals are: 1) to trace the local changes in peat and carbon accumulation between 15,5-10 kyrs BP at subcentennial scale resolution; 2) to estimate the influence of post-glacial hydroclimatic variability patterns on carbon rates of change. A 11m core was extracted from the centre of the peat bog pond. An age-depth model was generated using radiometric ^{14}C analysis data. Detailed stratigraphic descriptions were performed applying standard methods and X-ray fluorescence core scanner analyses. To investigate the origin of the organic matter and its variability through time, organic proxies from bulk sediments samples are being analysed: carbon to nitrogen atomic ratio (C/N), total carbon (TC) and total organic carbon (TOC), total nitrogen (TN), as well as carbon and nitrogen isotopes (δ13C and δ15N). Paleoecological (pollen, diatoms) and geochemical variables will help deduce the concurrent environmental shifts occurred during the study period.

Understanding the dynamic of phytoplankton and managing rates of ecological change in a peri-urban lake (eastern China) in the Anthropocene

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Freshwater blooms of phytoplankton threaten public health and depress ecosystem services globally in the fast-changing Anthropocene. Understanding the long-term dynamics of the phytoplankton community is a priority for future lake management and restoration, especially for those intensively populated areas. Here we used a century-scale paleoecological investigation from a peri-urban lake Luoma Lake in eastern China to reconstruct the phytoplankton community composition, algal abundances and the historical ecosystem dynamics evidenced by sedimentary pigments. High-resolution analysis of phototrophic pigments revealed a substantial increase in abundances of total algae, cryptophytes, siliceous algae, chlorophytes, and cyanobacteria at a surprising rate after the 2000s, followed by a declined trend in recent years. The interaction of substantial nutrient loads from urbanization, aquaculture and agricultural practices, and climate warming was identified to account for the shift in the phytoplankton community of Luoma Lake. Whereas, both pigment assemblages and geochemical records captured the potentially ecological recovery signal of Luoma Lake recently, which was attributed to the nutrient reduction program in the watershed (e.g. limited aquaculture activities). Given the potential effect of future climate change on phytoplankton, especially cyanobacteria, we further projected the time series of future total algae and cyanobacteria abundances based on two different climate scenarios (shared socioeconomic pathway 1-2.6 and 5-8.5) to mid-21st century. On average, higher phytoplankton and cyanobacteria abundances were projected due to the rising temperature. Furthermore, rates of ecological response of phytoplankton will rapidly increase as the temperature accelerated even if the reduction in nutrients, suggesting the alleviated/diluted effect of reduced nutrients by climate warming in the future landscape. This study emphasizes the necessity of understanding the dynamics of phytoplankton, incorporating rate-focused strategies into future lake management and combining regional nutrient reductions with mitigating against global warming to avoid accelerating the nauseous phytoplankton blooms, especially for those urban/peri-urban lakes.

Response and recovery of a NE European Sphagnum peatland affected by cement dust pollution

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Peatlands are important global sinks and stores of organic carbon. In recent centuries, many have been degraded by human disturbance, directly (e.g., by burning or drainage) and indirectly (e.g., by industrial pollution and climate change). Ombrotrophic (rain-fed) peatlands are particularly sensitive to aerosol pollution, as they receive their nutrient supply solely from the atmosphere.

In Estonia, atmospheric pollution emitted during the mid to late 20th century was unusually base-rich, consisting mainly of particulate emissions from industrial plants, such as the Kunda Nordic Cement factory. This site began large-scale production during the 1960s, emitting vast quantities of cement dust into the surrounding area. These emissions caused nearby peat-bogs to become more alkaline and drove declines in *Sphagnum*, an important peat-forming moss. By the late 1990s, filters were used to limit further emissions from the factory.

Our study aims to examine the impact of alkaline dust deposition on ecosystem functioning in a formerly ombrotrophic peat bog (Varudi bog, NE Estonia), as well as its subsequent recovery following the removal of the point source of pollution. We will apply a suite of palaeoecological methods to two peat cores from our study site, reconstructing past changes in acidity using testate amoeba as a proxy for pH. Our reconstruction will be compared with historical records of cement production from the Kunda factory to test its reliability. Finally, we will relate these pollution histories to the site's vegetation and carbon accumulation dynamics. This will allow us to define threshold values for shifts in ecosystem functioning in response to alkalinisation and thresholds for later recovery.

This work will improve our understanding of how peatland ecosystem dynamics have responded and continue to respond to past anthropogenic disturbances. This understanding can inform best practices for restoring and managing heavily polluted peatlands.

The resilience of small kettle hole peatland to the disturbance caused by climate change and land use during the last 2,000 years (N Poland)

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The recent 2000 years have been marked by environmental changes caused by human impact and climate change. Intensive human activity on the environment (such as fire, deforestation, land use, or drainage) has had a significant impact on changes in the geomorphological processes, hydrological cycle, and vegetation. That is why it is so important to understand the dynamics of these processes and understanding the factors responsible for the transformation of the environment and the impact of these changes on the peatland ecosystem - important reservoirs of water, carbon, and archives of the past. Therefore, the main aim is to investigate the resilience of Nicemino peatland to the disturbance caused by climate change and land use during the last 2,000 years. For this purpose, we used a peat archive with high-resolution multi-proxy analyzes. The chronology of the peat monoliths is based on the twelve AMS^{14}C dates. To reconstruct local and regional vegetation changes we used pollen and plant macrofossils, whereas testate amoeba was used to reconstruct the past hydrological variability. Macro-charcoals have provided information about the paleo fires and geochemistry gives us an overview of the relationship between human activity, past hydrology, and catchment processes. The Nicemino is a small Sphagnum kettle-hole peatland (3 ha). The main reason why was selected this site as the object of the study was the presence of a large number of relict's charcoal hearths indicating the intensive transformation of the natural environment by man in the immediate vicinity of the peatland. Our preliminary results show a clear transformation of the vegetation species composition in the past, caused by climate variability and human activity (i.e., agriculture, forest management, or charcoal production in charcoal hearths), which undoubtedly could have caused changes in the peatland ecosystem. Despite the existence of many paleoecological studies in northern Poland, there is still a lack of high-resolution research multi-proxy with a detailed chronology that would support the history of changes in land use and would provide new paleoecological data from sediment archives not yet explored. This research is part of the project funded by the Polish National Science Centre (No. 2018/31/B/ST10/02498).

Plateau icefield glaciation of the Canadian Prairies: a geomorphic reconstruction

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The Younger Dryas Stadial was a period of rapid, high magnitude cooling that occurred immediately prior to the onset of the present interglacial, and is one of the most intensively studied events in the palaeoclimate record. The response of glacial systems during this abrupt event offers a valuable analogue, allowing a better understanding of the rate of glacial advance and recession with respect to recent and future climate change. Within the Northern Hemisphere, renewed glacial conditions during the Younger Dryas led to the growth of plateau icefields. These localised icefields are particularly sensitive to variation in climate and therefore provide a unique record of local palaeoclimatic conditions. The development of Younger Dryas Stadial plateau icefields associated with regional ice sheet deglaciation has been well documented for regions covered by the Fennoscandinavian and British-Irish ice sheets, where the concept has been employed to make detailed local and regional palaeoclimatic reconstructions. In contrast, the potential existence of plateau icefields in regions deglaciated by the Laurentide Ice Sheet has so far been overlooked, despite the widespread occurrence of suitable topography and some evidence for Younger Dryas readvances in North America. Here we evaluate the evidence for potential, Younger Dryas aged, plateau icefields and their associated landsystem signatures within the Canadian Prairies using newly available high resolution LiDAR imagery.

Insights from calibrating Greenland Ice Sheet model simulations against the record of Last Glacial and Holocene ice marginal variations

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The Greenland Ice Sheet holds an estimated ~7.4 m of sea-level equivalent and is currently experiencing rapid recession due to global warming. While accurate projections of future ice sheet mass loss are essential to plan for sea level change, current projections of the Greenland Ice Sheet's response to present-day and future climate change yield large uncertainties and vary significantly between simulations. Because climate changes on shorter timescales than the response of continental ice sheets, recent work suggest the current Greenland Ice Sheet is not in equilibrium with climate and is instead affected by a complex product of past changes. This represents a challenge when starting projections of future ice-sheet evolution without accounting for past dynamics. The discovery of this lag in ice-sheet response and the growing library of geological observations enables us to ask the question: can a calibration of Greenland Ice Sheet model simulations against the geological record improve projections of its future behaviour?
To address this research question, we here show preliminary results from a new experiment that simulates the evolution of the Greenland Ice Sheet from the last glacial maximum (24 ka BP) to 1850 AD with the Parallel Ice Sheet Model (PISM). An ensemble of simulations was run at 4 km spatial resolution and forced by the latest transient palaeo-climate and ocean simulations of the isotope-enabled Community Earth System Model (iCESM 1.2 and 1.3). To compare these simulations against the empirical record, we also present a new database of Greenland-wide ice margin geomorphological mapping and a new compilation of radiocarbon and Terrestrial Cosmogenic Nuclide ages dating Greenland Ice Sheet Late-glacial and Holocene retreat patterns. The goodness of fit between a given ice-sheet simulation and this newly assembled empirical record of ice-sheet margin evolution is quantitatively assessed using a new set of algorithms developed internally as part of the PALGLAC project. With this investigation, our aim is also to provide new insight into the former Greenland Ice Sheet's response to transitional climatic phases including the last glacial termination, the Late-glacial/Holocene transition, and the Holocene thermal maximum.

Ice Sheet Speed-dating: Using Expert Elicitation to identify "good" simulations of the LGM North American Ice Sheets

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After running a large ensemble of palaeo ice sheet model runs, it is common to either rank the simulations or determine which simulations are an acceptable match to observations and which are ruled out. This task requires human judgement, which is usually left only to the authors of the research. Tools have been developed to compare ice sheet simulations to empirical reconstructions numerically, but even this approach requires some human input on values for match thresholds.

An alternative is to use expert elicitation to identify "good" ice sheet simulations. Expert elicitation normally captures expert's beliefs in the form of a probability distribution; for something as complicated as ice sheet geometry this is much too arduous a task. Instead, we propose to elicit binary classifications of "good" and "bad" and find descriptions of plausible ice sheets through probabilistic inverse modelling. Experts can consider empirical ice sheet reconstructions, but also "soft-knowledge" about the sectors of the ice sheet it is most important to match, margin shapes considered to be glaciologically plausible, and an idea of the reasonable best-reconstruction a model will be able to provide. By seeking the input of many experts, it is possible to both lighten the task load of determining the quality of 100-1000s of simulations, and gain a wisdom of the crowd benefit to the results. Just like any other method of ranking ice sheet simulations, this method requires human judgement; in this case more explicitly than usual.

We are seeking expert input to rank an existing ensemble of North American Ice Sheet simulations. By asking experts at the INQUA 2023 Rome Symposium to spend 3-5 minutes sorting simulations using an online interface we will build up an average community view on which LGM North American Ice Sheet simulations are "good". This will provide a community resource to compare future ice sheet simulations against that is a justifiable representation of academic expert knowledge, adding to the current arsenal of model-data intercomparison tools.

Reconstructing Cordilleran Ice Sheet stability in western Canada during the Last Deglaciation

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The Cordilleran Ice Sheet in western North America was of comparable size and topographic setting to the modern Greenland Ice Sheet and exhibited similar dynamics. Ice streams channelled rapid flow and the western ice margin terminated in both marine and terrestrial environments. Reconstructing Cordilleran Ice Sheet retreat can therefore provide a helpful analogue for how the Greenland Ice Sheet may respond to changing climate and underlying topography in the future. Moreover, deglaciation in this region controlled routes available for early human migration into the Americas. Here, we present cosmogenic ^{10}Be nuclide exposure ages from glacial erratics and bedrock on the west coast of British Columbia (53.4°N, 129.8°W) that add to existing chronologies along ~600 km of coastal North America. Collectively, these data show deglaciation back to the present coastline by *ca.* 18–16 ka. Retreat then slowed and ice seemingly stabilised close to the present coastline for several thousand years until *ca.* 14–13 ka. Ice may still have been lost during this period of relative stability, but through vertical thinning rather than lateral retreat. We attribute initial retreat to destabilisation and grounding line retreat resulting from rising sea level and/or ocean warming in the northern Pacific. Subsequent stability at the present coast was likely due to the transition from marine to terrestrial margins despite increasing temperatures that may have driven ice sheet thinning. Hence, we show the importance of understanding both climatic and non-climatic drivers of ice sheet change through time. We also show that hundreds of kilometres of coastline were free of ice prior to an important period of early human migration into the Americas.

Shelf-edge terminating glaciation offshore of northeast Greenland during the Last Glacial Maximum and timing of initial ice sheet retreat

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The Northeast Greenland Ice Stream (NEGIS) is the largest ice stream to drain the Greenland Ice Sheet (GrIS) today. The ice stream has undergone recent (post 2010) grounding line retreat and ice shelf loss but the longer-term history of the NEGIS, particularly on the adjoining continental shelf is poorly constrained. Marine geophysical data on seafloor geomorphology and acoustic stratigraphy, combined with radiocarbon dated sediment cores allow reconstruction of the maximum extent of the NEGIS at the LGM and the timing of initial ice sheet retreat on the outer continental shelf offshore of northeast Greenland. In this region two major cross-shelf bathymetric troughs, Westwind and Norske troughs, acted as pathways for offshore-directed ice flow across the wide northeast Greenland shelf during the last glaciation. The seafloor geomorphological and acoustic data reveal a range of flow parallel and flow transverse glacial landforms in the outer shelf sections of both troughs. Mega-scale glacial lineations record former streaming flow towards the shelf edge. Flow transverse landforms in the form of grounding-zone wedges record episodic grounding line retreat inshore from the shelf edge and across the outer-mid shelf during deglaciation. Sediment cores from the troughs recovered subglacial tills and grounding-zone proximal sediments overlain by deglacial stratified glacimarine sediments which record ice sheet advance and retreat. Beyond the shelf edge of Norkse Trough the continental slope is characterised by glacigenic debris flows typical of submarine slopes offshore of shelf-edge terminating palaeo-ice streams. Radiocarbon dating of deglacial sediments in the shelf cores indicate that initial post-LGM retreat of the palaeo NEGIS from the northeast Greenland shelf edge was underway relatively early in comparison to some other sectors of the GrIS and that retreat rates across the outer shelf were slow. The dates provide the first direct chronological support for a shelf-edge terminating GrIS offshore of northeast Greenland during the LGM.

Evidence for major British-Irish Ice Sheet expansion during Marine Isotope Stages 4 and 3 and implications for glacial-isostatic adjustment and high relative sea-levels

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The recent integration of terrestrial and marine geomorphological, stratigraphic and geochronological data constraining the maximum advance and retreat dynamics of the last British-Irish Ice Sheet (BIIS) 31,000 to 15,000 years ago (BRITICE-CHRONO Project) highlighted some datasets and observations that could not be readily assimilated or that are anomalous against the weight of the independent evidence. Whilst some of these clearly relate to technical errors in e.g. geochronology, others, together, give clues as to the behaviour of the ice sheet prior to the Last Glacial Maximum (LGM) during the last cold stage. A series of independent datasets are reviewed here that together provide evidence for significant advance(s) of the BIIS prior to the LGM during Marine Isotope Stages (MIS) 4 and 3. These datasets include the timing of significant ice-rafted detritus flux into the adjacent deep northeast Atlantic, clearly indicating a calving margin; cosmogenic rock-exposure age dating of glacially-eroded surfaces in southwest England and in Wales indicating extensive and thick ice, and optically-stimulated luminescence (OSL) dating evidence for glacifluvial/deltaic sand deposition from northwest Lewis (Outer Hebrides). These data relating directly to ice sheet reconstruction are supported by OSL dating of raised beach sequences in southern Ireland, previously interpreted to be interglacial, to MIS 4 and 3. The most significant eustatic lowstand prior to the LGM was during MIS 4, of ~80 m. The elevation of the southern Irish raised beaches implies a glacial-isostatic adjustment (GIA) deflection of 80 m along this coast which equates to minimum ice thicknesses > ~ 400 m. High relative sea-level during MIS 4 and 3 serves to explain the existence of giant erratic boulders around the coasts of Britain, known but unexplained for over 150 years.

Evaluation of the role of the Baltic Sea depression during deglaciation of the last Scandinavian Ice Sheet: a landform-driven investigation

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The landforms left behind by the Last Scandinavian Ice Sheet (SIS) offer an opportunity to investigate the controls on the ice sheet dynamics. The modern-day terrestrial sectors of the last SIS have seen considerable attention by landform and stratigraphic investigations. Due to a lack of bathymetric data in the Baltic Sea, this region has seen a more limited sector-scale investigation despite its geographical importance in understanding SIS dynamics during the last deglaciation. The Baltic depression hosted the extensive Baltic Ice Lake, which has been suggested to have had a considerable control on SIS dynamics, providing an aqueous calving front that may have resulted in a rapid collapse of this ice sheet sector. Both ice sheet scale investigations and regional studies at the southern periphery of the SIS have considered the Baltic depression as a conduit for ice towards the southern ice margin throughout the whole last glaciation. Here, we test these hypothesis by using newly available bathymetric data and peripheral topographic data. These data reveal, for the first time, an extensive landform suite stretching from Denmark (W) to Estonia (E) and southern European coast to Aland Sea (0.3 million km2 region) that allow us to reconstruct the ice dynamic history of the Baltic SIS sector. Landform evidence indicates a complex retreat pattern that changes from lobate ice margins and splaying lineations to parallel MSGL in the deeper depressions of the Baltic Basin. Ice margin still stands on underlying geological structures indicate the likely importance of pinning points during the ice retreat resulting in a stepped retreat pattern. Over the length of the study area we identify broad changes in ice flow geometry, from SE-NW to N-S and back to NW-SE, likely resulted from a migration and reconfiguration of ice divides during deglaciation.
This work was supported by the Polish National Science Centre (NCN) under Grant 2015/17/D/ST10/01975. CC, SL, CD were supported by the PalGlac project funded from the European Research Council (ERC) under the European Union’s Horizon 2020 research and innovation programme (Grant Agreement No. 787263).

Updating the limits of the postglacial marine transgression along western Hudson Bay in mainland Nunavut and northern Manitoba, Canada

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The revised maximum limit (ML) of the Tyrrell Sea on the western side of Hudson Bay in mainland Nunavut and northern Manitoba provides robust constraints for glacio-isostatic adjustment models and the deglacial history of the region. The new compilation updates previous mapping of ML features, making use of high-resolution digital elevation models (DEM), new field-based observations and digital compilations of supporting datasets (marine deltas and sediments). DEM-extracted median elevations on 1595 features vary from 83 to 242 m asl (±1 m in Nunavut; ±1-15 m in Manitoba) between Churchill, Manitoba, and areas within the Arctic Ocean drainage basin in Nunavut. Regionally, the high values above the median of □140 m reflect the proximity to a former ice-load centre of the Laurentide Ice Sheet (i.e. Keewatin Dome). However, the high elevations >200 m on the west side of Committee Bay are interpreted to result from incursion of the sea into depressed areas during the early phases of deglaciation. In contrast, the particularly low elevations at 82-110 m in inner Wager Bay suggest that remnant ice masses under the Keewatin Ice Divide (KID) prevented incursion of the sea late during deglaciation. Similarly, low elevations at □100 m near Baker Lake indicate that ice remnants blocked invasion of the sea over the last position of the KID, as supported by relatively young ages on marine shells in this area. From Baker Lake, the ML increases westward to 150 m, and southward from 125 m, to 161 m at the Nunavut border and 165-175 m at Seal River, and then decreases to 145 m at Churchill River. These changes are related to contrasting ice loads associated with migration of the KID and/or different configurations and ages of the retreating ice margins. During deglaciation, proglacial lakes were also in contact with the ice margin, namely in the Thelon River basin and in northern Manitoba, complicating the delineation of accurate marine limits. More detailed mapping and additional ages are needed to decipher the location of, and drivers for, the changing marine limits in these areas and relationship with the history of the proglacial lakes.

Deglaciation of the Cairngorm plateau, constrained with in situ cosmogenic 10Be and 14C measurements

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Highland landscapes in past-glaciated regions often have perplexed Quaternary geologists, as high-elevation exposures of weathered bedrock belie landscapes much older than glacially abraded landscapes found at lower elevations. This juxtaposition of geomorphic regimes is due to one of two scenarios: 1) weathered highland surfaces were nunataks during recent glaciations and underwent sustained sub-aerial weathering, 2) highland landscapes were encased by non-erosive ice during recent glacial periods. These regions are thus interesting targets for geochronology, as information gained from high-elevation sites has the potential to provide limiting constraints on ice sheet thickness, either over the course of a glaciation, if a nunatak existed, or due to thinning during deglaciation, if covered by non-erosive ice. Cosmogenic surface exposure dating is frequently used to constrain spatio-temporal patterns of ice cover, yet landscapes resulting from minimally erosive glacial ice cover, or lacking past ice cover, commonly exhibit apparent exposure ages much older than the timing of regional deglaciation, when using long-lived radionuclides such as ^{10}Be, ^{26}Al, or ^{36}Cl. These apparently 'old' exposure ages are due to nuclide inventories remaining from previous ice-free periods, which have not been removed during subsequent glaciations.

The Cairngorm Massif in central Scotland is a classic example of such a landscape reflecting long-term preservation and subaerial weathering, with numerous tors and blockfields. Previous studies in the Cairngorms, combining geomorphic evidence and paired cosmogenic ^{10}Be/^{26}Al, indicate a landscape preserved beneath non-erosive ice, perhaps for multiple glaciations. However, in situ cosmogenic ^{14}C has a 5.7 ky half-life that renders it most sensitive to deglacial histories only in the last ~20 ka. We use paired ^{10}Be/^{14}C extracted from bedrock and glacial erratic samples collected on the Cairngorm Plateau to investigate the timing of the most recent high-elevation deglaciation. This multi-isotope approach enables constraints on deglaciation timing and allows assessment of potential complex burial/exposure histories during deglaciation. These new measurements will thus constrain deglacial histories at our high-elevation sites, providing insight into ice mass thinning and the spatial pattern of glacial erosion.

From summits to cirques: Deciphering the nature and rate of ice loss from the last Welsh Ice Cap

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Ice sheets are currently melting at unprecedented rates and through thinning and fragmentation will yield new, peripheral ice caps in the future. Understanding the stability of these peripheral ice caps through ongoing climate change is important for determining future meltwater production, but requires robust reconstructions of the development and demise of similar ice caps in the past. The British-Irish Ice Sheet covered most of Britain, Ireland and the North Sea during the Last Glacial Maximum (LGM), and comprised numerous accumulation centres including a substantial ice cap over Wales. The Welsh Ice Cap decoupled from the main ice sheet during deglaciation at 20-17 ka, with thinning and receding ice exposing upland areas prior to complete deglaciation. Consequently, Wales presents a unique geological testbed for examining peripheral ice cap development and loss: from an ice cap abutting an ice sheet, to separation, thinning, cirque glacier development, and complete deglaciation. However, despite substantial recent advances in our understanding of British-Irish Ice Sheet retreat, the nature and rate of Welsh Ice Cap deglaciation remains limited.

This study presents a compilation of glacial geomorphology from across Wales. We highlight gaps in the geomorphological record for targeted investigation and high-resolution mapping of smaller-scale ice recessional landforms in the future. Our new geomorphological mapping will be used to reconstruct the nature of Welsh Ice Cap retreat and guide a campaign of detailed geochronological work to better understand the rate of ice cap loss through time. Cosmogenic exposure dating of glacial landforms and radiocarbon dating inter-morainal lake/bog sequences will help establish chronological time-steps. Schmidt Hammer exposure dating will provide additional age control and biostratigraphy will also be used as to help subdivide moraine sequences. Improved constraints on the timing and nature of deglaciation in Wales will offer important insights into the development and loss of peripheral ice caps in mountainous areas in the future. Moreover, the response of Welsh ice to Late-glacial climate oscillations (Oldest Dryas, Bølling–Allerød, Younger Dryas) will add to our understanding of Northwest Europe's wider environmental history during the last termination.

Towards a high-resolution palaeo-ice sheet reconstruction on the Antrim Plateau, NE Ireland

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Northeast Ireland presents an excellent testing ground for understanding the complex interactions between ice, landscape, and climate at the confluence of multiple major palaeo-ice streams. A combination of sea level rise, tidal forces, ice divide and thaw point migration, sea-surface temperature rise, and ice over-extension drove the collapse and demise of the Irish Sea, North Channel, and Malin Sea ice streams from c. 23-16 ka BP. However, even the most recent empirical and model British-Irish Ice Sheet reconstructions fail to capture the spatiotemporal complexity of their final demise. These reconstructions are hindered by relatively low-resolution glacial landform mapping and an absence of robust, precise chronologies, both in the onshore and offshore realms of NE Ireland. Consequently, this challenges our ability to constrain palaeo-ice sheet and ice stream retreat and terrestrial deglaciation over a substantial area, inhibiting out ability to understand the atmospheric, oceanic and dynamical factor driving mass balance changes.

This project aims to reconstruct palaeo-ice sheet dynamics on the Antrim Plateau (Northern Ireland) using high-resolution geomorphology and multiproxy chronostratigraphy. We seek to produce the first comprehensive combined tephrochronological and cosmogenic nuclide chronological framework to improve understanding of ice dynamics in NE Ireland. Geomorphological mapping on the Antrim Plateau using a 0.4 m resolution digital surface model is providing unprecedented detail on the nature of ice retreat. Our newly mapped ice limits challenge previous assumptions about the nature and extent of a Scottish readvance. The identification of widespread hummocky, kettle-kame topography provides insights into a large, stagnating ice mass on the plateau. Finally, with such high-resolution imagery, we can evaluate evidence for a (semi-)independent ice cap in the Antrim Hills, which could provide yet more insights into the influence of climate and ice dynamics at much smaller scales.

This presentation will display initial geomorphological mapping of the Antrim Plateau, including ~8,000 individual landforms and new ice margin interpretations. It will also provide discussion points on the future chronological work we aim to carry out as part of this project in order to produce a high-resolution ice sheet reconstruction on the plateau.

Ice-flow reconstruction and deglacial patterns in the west-central Keewatin Sector of the Laurentide Ice Sheet (Northwest Territories and Nunavut, Canada)

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Reconstructions of the evolution of the Laurentide Ice Sheet (LIS) since the last glacial maximum (MIS2; <29 ka) provide a framework for understanding changes in ice extent and dynamics that are essential to a wide range of studies such as paleogeographic reconstructions, glaciological and glacial isostatic adjustment modeling, sea-level changes, ice-dammed lakes reconstructions, and mineral exploration. The LIS was comprised of three major domes located in northern remote regions of Canada that until recently, have not been the focus of extensive field studies and therefore, knowledge gaps remain. The Keewatin Dome formed one of these major domes and was located in Northwest Territories and mainland Nunavut (Canada) where recent work suggests complex glacial history resulting from ice divide migration, ice streaming, and landscape preservation over multiple glacial events. Yet, these landsystems remain mostly unmapped and undated, and therefore uncorrelated at the regional scale. To address this lack of regional knowledge on glacial history and building on a new compilation of glacigenic features and landsystems in eastern Keewatin (McMartin et al., 2021), an activity has been initiated as part of Canada's Geo-Mapping for Energy and Minerals (GEM) GeoNorth program (2021-2026) to provide a glacial geology framework for the west-central Keewatin region supported by targeted field investigations and high-resolution digital mapping. Here, we present preliminary results from the compilation and mapping activities showing how ice flow was organized around the ice divides and how it evolved during deglaciation. This high-resolution mapping also unveiled a suite of ice-marginal landforms (moraines, channels, spillways) that reveal the local ice retreat patterns and their implication in the development of glacial lakes. These preliminary interpretations will guide fieldwork investigations which will aim at collecting targeted geochronology (terrestrial cosmogenic, luminescence and radiocarbon) samples to support the refinement of known deglacial chronologies.

McMartin, I., Godbout, P.-M., Campbell, J.E., Tremblay, T., and Behnia, P., 2021. A new map of glacigenic features and glacial landsystems in central mainland Nunavut, Canada. Boreas 50, p. 51–75. doi:10.1111/bor.12479

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Vegetation and hydrological reconstruction in the Makgadikgadi paleolake during the Cenozoic using biomarkers

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Understanding long-term climate change (Miocene to present) in Southern Africa is crucial to explain past hydrological variability in the region, but also to better predict future environmental changes. For example, during the warm Pliocene epoch, the pCO_2 was ~400 ppm and this region has been modelled to be wetter than present (dense vegetation and numerous lakes, Burls and Fedorov, 2017). This is in stark contrast to what has been forecasted by the current models (IPCC report 2014). The Makgadikgadi paleolake system (Northern Botswana) is centrally located, within a key region for understanding African vegetation history and the collapse of forest and woodland vegetation during the long process of Neogene aridification. A combined climate and vegetation study can elucidate the drivers in climate and vegetation change over the Cenozoic.

To reach this aim, we will reconstruct paleoenvironmental conditions (e.g., vegetation, aridity, soil input) in and around the Makgadikgadi Paleolake, where a 207 m-long sediment core was retrieved in 2022 (funded by an USA-NSF INTEGRATED EARTH SYSTEMS Collaborative Research and an ETH research grants). Specifically, we will target biomarker lipids, that are molecular remnants of bacteria, archaea, phytoplankton, plants and animals. Their structural diversity and isotopic composition can be related to the environmental condition in which their biological source organisms were growing. Following erosion of surface soils or settling from the water column, and incorporation in the sediments, these lipids constitute a part of the geological archive that allows to reconstruct unique biological processes. In particular, we will present data (of 50 samples) from branched GDGTs as indicator of temperature and soil aridity, archaeal membrane lipids as an indicator for salinity, as well as long-chain fatty acids to trace changes in vegetation in the catchment, and their specific isotopes to reconstruct changes in vegetation, precipitation and lake evaporation. We will frame this climate reconstruction in a preliminary age model.

Palaeoenvironments of the Cape Floristic Region: New research & current developments

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The Cape Floristic Region (CFR) is a key focus area within southern Africa due to its botanical importance in terms of high levels of biodiversity as well as its rich cultural and archaeological heritage. The area is highly sensitive to cycles of regional and global environmental change, and records obtained from the region provide valuable information regarding past climate variability. Prior to the last decade, few high resolution palaeoenvironmental records were recovered from the region, and its environmental history remains relatively poorly understood. This presentation summarises the research initiatives currently being undertaken by Nelson Mandela University's Palaeoecology Laboratory. This ongoing work aims to provide a comprehensive understanding of climate, biodiversity and human-environment interactions within the CFR, with a particular focus on the understudied eastern subregions.

The records presented are derived from unique natural archives found within the CFR including rock hyrax middens and coastal lowland wetland deposits. These archives are being analysed within a multi-proxy, multidisciplinary framework, using pollen, fungal spores, micro- and macrocharcoal, diatoms and geochemistry to elucidate changes in vegetation, herbivory, fire, hydrology and climate.

This work is designed to actively develop regional capacity, using the new Palaeolab and engage students and early career scientists from the area to contribute to the development of fundamental knowledge regarding their environment and history.

Climatic and Cultural Dynamics in West Africa's Sahel: a view from Surame, Nigeria

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The development of large settlement mound complexes in parts of the West African Sahel in the early 1st millennium AD is seen as related to a more favourable climatic condition. Rainfall in the Sahel was much higher by that time. By the first half of the 2nd millennium AD, massive site abandonment was interpreted to have resulted from increasing aridity. Growing evidence suggest that in central West Africa, the fifteenth century AD saw the rise and/or expansion of states and empires, major shifts in settlement patterns, and growth of new trading connections between the forest and Sahel. This presentation responds by using excavations of two trenches (2 X 3 metres and 3 X 3 metres) of Surame's deposits to document and explore culture as an adaptive system, in the patterns of continuity and change in subsistence behaviour. Surame covers approximately 1, 214 hectares with its gateways within the inner and outer settlement walls, and numerous circular and rectangular surface structures which occur both singly and in groups.

Tracing the impact of Walker Circulation changes on pan-African climate variability during the past 550,000 years using proxy and model results

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Spatio-temporal changes in the strength of the Walker Circulation, a belt of tropical convection cells along the equator, have been recently proposed as a predominant driver of pan-African climatic variability on quaternary time scales. These changes are thought to be strongly influenced by variability in the Earth´s orbital ellipse (i.e., eccentricity cycle) which varies on time scales of c. 400,000 and c. 100,000 years. This newly developed, tropically based, climate framework provides a new basis for understanding past vegetation change and testing hypotheses regarding hominin evolution, development, and the dispersal across the African continent. Insights into past Walker Circulation changes have thus far been exclusively gleaned from the small number of marine and terrestrial proxy records that detail Africa´s climate history over 100,000 of years. Therefore, to explore the spatio-temporal coherence of the Walker circulation variability framework across Africa this study aims to: (i) compare these proxy record results with output from an intermediate complexity Atmosphere–Ocean Global Climate Model (GENIE-PLASIM) during the past 550,000 years to reconstruct spatio-temporal changes in the Walker Circulation, (ii) elucidate potential driving mechanisms of Walker circulation changes through time and space, and (iii) assess the potential impact of these Walker Circulation changes on pan-African moisture availability and vegetation changes. The latter might provide new insights into the availability of resource-rich and stable ecotonal settings, thought to have been important to early modern humans, during the Middle and Late Pleistocene.

Towards Deep Drilling in the Turkana Basin (DDTB): Tracking the Environmental Forces Driving Hominin Evolution

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The Turkana Basin (TB), Kenya, in the East African Rift System (EARS) provides an unparalleled opportunity to recover a continuous and high resolution 4 Ma record of the Earth-life system through scientific drilling. This archive will be unique as it **a)** tracks the tectonic and magmatic development of the TB and EARS, **b)** constrains controls on regional climate and hydrological responses, **c)** links dynamics of faunal/floral communities and cultural development with environmental parameters, **d)** spans the range of hominin evolution from ~4 Ma to present, and **e)** covers the interval of significant hominin technological (i.e. stone tool) development. The Deep Drilling in the Turkana Basin (DDTB) project aims to recover a novel, long sedimentary record to minimize the impact of spatial paleoenvironmental variability on paleoclimatic and tectonic reconstructions, and provide insight into the sequence and significance of climate and environmental change over the last 4 Ma in this key paleoanthropological locality. The project will significantly advance existing paradigms surrounding rift development, climatic and environmental change, and the evolution of hominins and their associated ecosystems.

Here we present the outcomes of our ICDP-funded scientific drilling workshop, held in July 2022 in Nairobi, highlighting the communities' need for a record that will address questions in the four topical core areas: paleoclimate, paleoenvironment, basin evolution, and modern lake systems. The proposed two-phase scientific drilling campaign will facilitate the retrieval of long cores in an onshore transect in West Turkana that will comprise 4 Ma –750 ka and a series of offshore cores from the modern lake covering the last 750 ka BP. Together these records will complement and leverage previous outcrop and core investigations, fill critical gaps in existing paleorecords, and enable a more complete integration of environmental records with the unique evolutionary archive of the basin.

Terrestrial ecosystem change during critical periods of early hominin evolution in SE Africa over the past 4 Ma

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To study the nature and tempo of terrestrial ecosystem change in SE Africa during critical periods of hominin evolution in the Plio/Pleistocene we have generated a continuous environmental and climate record for the region spanning the past 4 Ma at an orbital-scale resolution (c. 15 kyrs). This record is based on multi-proxy analyses from IODP Site U1478 (Mozambique Channel), which is a sensitive recorder of sedimentological changes in the Limpopo River catchment area of SE Africa. To gain insight into vegetation variability we generated palynological and plant wax-derived carbon isotope ($\delta^{13}C$) data, and performed pollen-based climate reconstructions. We subsequently compared our datasets with available X-ray fluorescence core scanning data, TEX_{86}-based sea-surface temperatures and plant wax-derived δD_{wax} from the same core as well as other regional and global climate records, providing the background boundary conditions for hominin evolution in SE Africa since the Pliocene. Our record reveals a dominance of savanna (including Poaceae) and fynbos-like heathland (including Cyperaceae) biomes during the past 4 Ma. The data suggest alternating vegetation states, with glacials being dominated by fynbos-like heathland and interglacials by savanna. Additionally, we record a long-term trend of decreasing savanna and increasing fynbos-like heathland pollen abundances starting at around 2.8 Ma. Pollen-independent evidence for vegetation change at 2.8 Ma is provided by the increase of high (^{13}C enriched) carbon isotope values indicating an expansion of arid-adapted C_4 plants. This ecosystem turnover is associated with a slight decrease in reconstructed annual precipitation (from ~750 to ~700 mm) and a strong sea-surface temperature decline in the SW Indian Ocean by 4°C. The timing of ecosystem change suggests a connection to the intensification of the Northern Hemisphere Glaciation during the late Pliocene. We propose that the atmospheric CO_2 decrease during the late Pliocene facilitated the expansion of C_4 plants and fynbos-like heathlands without a significant decrease in precipitation. The considerable terrestrial ecosystem change in SE Africa at around 2.8 Ma may have been crucial for the evolution of early hominin species (e.g., *Australopithecus africanus*) in southern Africa.

The role of tropical climate systems in driving humidity during the African Humid Period

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The African Humid Period (AHP; c. 14,800 to 5,500 years ago) was characterized by elevated lake levels and shift towards moisture loving vegetation across much of Africa. The pattern of increased moisture availability during the AHP is, however, spatially and temporally variable and the climate mechanism(s) and feedback driving these changes remain ambiguous. In this study, we hypothesize that changes in the Walker Circulation system, driven by shifts in tropical Pacific sea surface temperatures, modulated the delivery of moisture across Africa and drove the spatial and temporal patterns observed during the AHP. To test this hypothesis, we extracted past climate change information from 16 pollen records from across Africa spanning the last c. 20,000 years and compared these records to the patterns of moisture balance change obtained from independent sea surface temperature records. Pollen records were extracted from the African Pollen Database within the Neotoma Paleoecology Database and were plotted against time using the dating control points provided by the original authors to create new standardized chronologies. The signal of past climate change from the individual records is characterized using two approaches, through: (i) the signal of past climate change from individual records, and (ii) performing probabilistic climate reconstructions (CREST; Climate REconstruction SofTware). Comparison between the past climate change reconstructions from Africa and the sea surface temperature records was achieved by performing a Principal Components Analysis. Our analysis identified an east to west gradient in the timing of the AHP as would be anticipated from changes driven by shifts in the Walker Circulation, however, sub-regional variations in the timing and direction moisture availability change were also evident. This highlights the importance of considering local conditions, as well as global climate factors, when interpreting individual records of past climate change in Africa.

Coastal lithofacies appraisals of Quaternary sequences in Dahomey Basin, southwestern Nigeria: implications of the granulometrical, palynological and isotopic studies

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An appraisal of the Quaternary sediments were carried out using ditch samples retrieved from drilled wells at three different locations in Lagos area. This is to evaluate the provenance, depositional environment, maturity and palaeoclimatic changes.

A total of forty two samples (sandstones) were used for the granulometric analysis, fifteen for heavy minerals and petrographic analysis, nine for palynological analysis, twelve pebbly conglomerates for morphometric studies and mollusk shells for isotopic study.

The results show medium to very coarse grained, moderately sorted to very poorly sorted (dominantly poorly sorted), strongly positive skewed to near symmetrical and very platykurtic to extremely leptokurtic indicative of river laid sediments suggesting high to low energy transporting medium. The heavy mineral assemblage is characterized by zircon(Z), tourmaline(T), rutile(R), garnet, epidote, staurolite, apatite and sillimanite suggesting igneous and metamorphic provenance. The average ZTR index is 53.9%, indicating texturally immature sediments. Petrographic results show the most abundant mineral (quartz) ranged from 90% to 95%.The QFR ternary plots suggest predominantly supermature quartz-arenites. Palynomorphs recovered from the wells show abundance of mangrove swamp forest palynomorphs including *Rhizophora* sp., *Avicennia africana* and *Acrostichum aureum* inferring marine deposit in a tidal swamp shoreline environment inhabited by mangroves community indicative of high sea level.

The occurrence of freshwater swamp forest species include *Arecidites* sp., *Mitragyna ciliata, Uapaca* sp. and *Botryococcus* sp. suggest mangrove dominated environment with high influx of freshwater. Pebble morphometric studies show littoral setting and the ratio of maximum projection sphericity and oblate prolate index suggest fluvial environment. The pebble forms are dominantly compact and compact bladed which further corroborate fluvial process. The oxygen(δ^{18}O) and carbon(δ^{13}C) isotope composition of the bivalves (gastropod) from Lekki well ranged from -4.93‰ to -2.94‰ VPDB (mean= -4.22‰) and -10.35‰ to -3.71‰ VPDB (mean= -7.43‰) respectively while Apapa well (shell fragments) revealed δ^{18}O values of -2.48‰ and -2.19‰ VPDB, δ^{13}C values of -3.27‰ and -1.96‰ VPDB. The results show positive correlation between oxygen and carbon isotopic compositions suggesting seasonal climate changes might influence carbon sources to some extent; however the estimated formational palaeotemperature was determined varying from 28.93^{o}C - 40.82^{o}C.

Keywords: Quaternary, palynomorphs, isotope, palaeoclimate, palaeotemperature

Late Holocene vegetation and climate of Wonderwerk Cave, South Africa, from charcoal

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The Wonderwerk Cave represents one of the rare cave sites in the arid interior of southern Africa that preserve multiple palaeoclimate indicators, such as pollen, charcoal, and phytoliths. Despite the large amount of charcoal excavated from the Holocene strata, pollen has been the most used indicator for Holocene environmental conditions. Pollen is less spatially precise compared to charcoal, hence this study is aimed to reconstruct the palaeoclimate of the area around the Wonderwerk Cave during the late Holocene by studying charcoal from one of the Late Holocene strata, Stratum 2b, which records the time between 2.3- 0.5 ka cal BP. The second aim of this study is to infer the human-plant interactions that were happening at that time. To do this, a sample of 50 charcoal fragments was studied, the wood they originate from identified, and climate and human-plant interactions inferred from the woody species identified. The sample was found to be dominated by shrubs or small trees that can tolerate dry environmental conditions, such as *Ozoroa paniculosa, Searsia lancea, Brachylaena huillensis, Commiphora sp., Maytenus undata, Olea europaea* subsp. *africana* and *Ziziphus mucronata.* This indicates that the environment was mostly dry. However, the presence of taxa that tolerate wetter environments such as *Heteropyxis natalensis, Olinia ventosa,* and *Berchemia discolor* suggests that rainfall patterns may have been variable. The presence of taxa that commonly grow near river banks suggests that there may have been a water source nearby, similar to Boesmansgat found 15 km from the cave. Overall, the results indicate a semi-arid climate and an open bushveld with a grassy layer, and small woody plants that enabled the humans occupying the Wonderwerk Cave to harvest wood, fruits, and medicine from them.

The scar of migration: sourcing for material evidences

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The nature, environment and climatic changes pushed and pushing man to migrate and change environment. In Africa and indeed in the Yorubaland of Southwestern Nigeria this migration left scars of movement in the material and non-material culture.

This paper presentation in poster identified series of evidences of migration and abandonment and concludes that at various time in the history of man, movements occurred and lefts evidences of the time and life of the people.

A pan-African spatiotemporal framework of the past one million years using advanced multi-record time-series analysis

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For several decades, eastern Africa was considered the origin of*H. sapiens*, documented by the oldest fossil finds from Omo Kibish (233±22 ka BP) and Herto (160–154 ka BP), from where the species was thought to have spread across the rest of the continent and beyond. Recent finds of human fossils and related stone tools in several parts of Africa between roughly 315–75 ka ago, i.e. Jebel Irhoud, southern Africa, Arabia, and eastern Africa initiated a lively discussion of a multiregional model of the origin and development of *H. sapiens.* The chronology and diversity of human fossils and archaeological remains, associated with a pan-African cultural patchwork, are underpinned by the availability of suitable and connected environments offering enough resources for our species to survive and reproduce. As new paleoanthropological research expands into poorly understood regions of Africa, the key to understanding emerging patterns of mobility and dispersal within and out of Africa is strongly linked to accurately reconstructed climate and environmental conditions in time and space. Here, we aim to create a spatiotemporal paleoclimatic framework for testing current hypotheses about a multiregional origin of our species. To do so, we collect and review suitable climate archives that cover the time since the Mid-Pleistocene Transition, the Mid-Bruhnes Event, and the late Pleistocene. Prerequisites for site selection are: (1) an age model without major gaps, (2) proxy data with a sufficient temporal resolution, precision, and accuracy, (3) a good understanding of the mechanisms that are represented by the proxy data, and (4) together they offer good geographical coverage of Africa's most important climates. We compare records using correlation analysis, such as windowed Spearman correlation, principal component analysis, fast Fourier transformation, and wavelet-based cross-spectral analysis. Furthermore, we analyze long-term trends, shifts, and transition types, that may have provided a catalyst for evolutionary changes, cultural innovation, and expansion/ migration, using e.g. breakfit regression, running Mann-Whitney and Ansari-Bradley test, and recurrence-based transition tests, such as recurrence quantification and recurrence networks. Here, we show the first results of our experiments.

Late Holocene Palaeoecology of Rainforest Reserve Sites

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The knowledge of environmental history of the tropical rainforests during the last Late Holocene is critical to addressing tropical biodiversity and climate change challenges. While that knowledge is increasingly becoming available in other tropical areas, such evidence of the Late Holocene environmental history of the tropical rainforests in Africa, from terrestrial sources in particular, is limited. Using palaeoecology and archaeological records from rainforest reserves (Okomu National Park and International Institute for Tropical Agriculture (IITA) forest reserve) in Nigeria, we reconstruct past climatic and environmental changes in the rainforests with attention on the response(s) of the rainforests to natural and anthropogenic impact. The pollen, sedimentology and archaeological data revealed three contrasting temporal environmental phases namely I, II and III. Phase I (*c.* 2000 BP- *c.* AD 1200) was characterised by a warm tropical rainforest that consisted of lowland rain forest, mangrove swamp and freshwater swamp forests, freshwater and fern communities; Phase II (*c.* AD 1200-*c.* AD 1700) witnessed marked decline in the rainforest in both sites, but grasslands increased at the IITA signaling the possible occurrence and severe nature of some dry climate. In the third phase III (*c.* AD 1700-Present), the rainforest became re-established; however, the appearance of the pollen of economic plants and herbaceous taxa associated with vegetation disturbance revealed the significant impact of humans. The data from the two sites documented the resilience and magnitudes of human impact on the rainforest and highlight the potentials of using palaeoecology in managing and addressing ecological restoration
Keywords: Palaeoecology, Forest reserves, Human Ecology, environmental history, West Africa

A multi-proxy paleoenvironmental reconstruction from the southeastern Ethiopian highlands during the Late Quaternary, as recorded in the sediments of Lake Haramaya

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Eastern African paleoenvironment is highly variable and influenced by global scale phenomena (e.g., changes in solar radiation due to orbital parameters) and by local and regional topography, i.e., the East African Rift System which bisects the Ethiopian highlands. Here, we present the first multi-proxy analyses of a 27 m long sediment core from Lake Haramaya, a highly fluctuating lake located on the Southeastern Ethiopian highlands, at an altitude of ~2000 m above sea level. Based on the sedimentation rate calculated from a dated short core in the basin, we assume our sediment core might cover the last ~100,000 years an important period of human dispersal within and out of Africa.

Geochemical proxies from ITRAX XRF scans, grain size analysis and concentration of total organic and inorganic carbon and nitrogen have been used for reconstructing the palaeoenvironment of the basin. Ca/Ti ratio is used as a reliable proxy for aridity, complemented by an inverse relationship with Rb/K ratio which is an often-used proxy for chemical weathering.

Lake Haramaya shows two distinct drier periods during which a carbonate dominated sediment was deposited. These extended dry periods were preceded and succeeded by unstable, relatively wetter periods during which silicate rich, sandier silty-clay, clastic sediments were deposited. These long-term dry and wet periods were interrupted by shorter scale minor fluctuations, identified in other proxies (such as Rb/K & K/Zr) beyond that of the Ca/Ti ratio.

Our results will help provide the environmental context to the human cultural change during the Middle and Later Stone Age, which are recorded from the nearby archeological sites (e.g., Goda Buticha & Porc Epic). The highland location of Lake Haramaya at the edge of the Main Ethiopian Rift and the Afar Depression adds further significance to the lake records, making them ideally suited to testing the refugium hypothesis.

Efficient identification of cryptotephra in marine sediment cores; a non-destructive approach

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Volcanic eruptions have punctuated New Zealand's geologic history for millions of years. Evidence of many of these eruptions occur as distal macroscopic tephra deposits found in deep marine sediment cores, often many hundreds of kilometres from source. As such, these macroscopic tephras likely provide evidence of only the largest eruptions, potentially introducing a preservation bias in the record. The recent development of cryptotephra identification, concentration, and quantification methods are allowing an increasingly detailed picture of volcanic activity to be uncovered.

Here we present a new method for identifying cryptotephra using non-destructive techniques (XRF, magnetic susceptibility, density) coupled with statistical, machine-learning techniques. Data collected from down-core scans are modelled to quantitatively discriminate and characterise the macroscopic tephra then, unsupervised machine-learning (e.g. Principle Component Analysis, PCA) and statistical techniques are used to identify potential cryptotephra within the dataset. New results generated during this period of method development have been applied to both targeted core sections, and full cores. Previously unidentified cryptotephra deposits have been isolated, characterised and used to further refine the code (developed in R statistical language) and unsupervised machine-learning approach. With the addition of detailed chronology for the cores (through radiocarbon dating), we comment on the timing of the volcanic events identified and the longevity of elevated tephra inputs (volcanic activity) into the marine sedimentary environment.

One-year record of drift pumice from the 2021 Fukutoku-Oka-no-Ba eruption, Japan, focusing on the amount, size, shape, and attached organism

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On 13 August 2021 (UTC+9), an eruption occurred at Fukutoku-Oka-no-Ba, a submarine volcano in the Ogasawara Islands (Bonin Islands). The eruption lasted for three days, with an estimated volcanic explosivity index of 4 and 0.1 km^3 of drifting pumice (AIST, 2021). As noted by Bryan et al. (2012), pumice drift associated with submarine volcanic eruptions has been recorded worldwide and is suggested to contribute to the spread of marine organisms. On the other hand, large-scale pumice drift in the present could be a disaster, causing damage to ship navigation and port facilities. Monitoring of such pumice rafts is possible if the area of the pumice raft is large enough to be seen on satellite images. However, once they have spread to some extent, their amount and locations become unknown, and it is difficult to track them by the time they drift ashore. Therefore, in this study, we conducted unprecedented drift pumice tracking on an island-arc scale (Japanese Islands). We analyzed samples collected on coasts mainly in the Japanese Islands during the first year after the eruption, focusing on the amount, size, and shape of pumice clasts that drifted ashore. We found that the amount and size of drift pumice decreased rapidly with time, indicating offshore diffusion and size decrease due to breaking and abrasion. Furthermore, we could record the variety and amount of attached organisms with time. In the future, we will revisit the coasts and observe the preservation process of pumice clasts washed ashore in order to discuss whether drift pumice layers in sediments show the age of eruption or not.

Characteristics and source volcanoes of drift pumice along the Pacific coast on the central to west of the Japanese Islands based on major element composition of volcanic glass shards

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In Japan, drift pumice clasts are found on most coasts despite no recent volcanic eruptions supplying pumice to the sea since before the 2021 Fukutoku-Oka-no-Ba (FOB) eruption. The FOB, a submarine volcano in the Ogasawara Islands (Bonin Islands), erupted on August 13, 2021, and numerous pumice clasts supplied to the sea were washed up on coasts in the Japanese Islands (Yoshida et al., 2022). Such extensive pumice drift is a low-frequency event among volcanic eruptions (Bryan et al., 2012). In this study, to clarify the source volcano and to discuss their supply and transport processes during no volcanic eruptions supplying pumice to the sea, we analyzed the major element composition of volcanic glass shards in drift pumice clasts.

We analyzed the pumice clasts (50-228 clasts per site) sampled at five coasts facing the Pacific Ocean from September 2018 to August 2019, that is to say, before being influenced by the 2021 FOB eruption and 20 tephras formed by past large terrestrial and submarine volcanic eruptions for reference. As a result, it is clarified that the source volcanoes of some drift pumice clasts are Aira caldera, Towada volcano, FOB, and submarine volcano NNE of Iriomotejima. The occurrence of the Aira-Tn tephra erupted from the Aira caldera (ca. 30 ka) formed wide pyroclastic flow plateau in the southern part of Kyushu Island (Machida and Arai, 2003). Therefore, we interpreted that reworking process of pyroclastic flow deposits is one of the major mechanisms of the continuous supply of pumice into the sea, regardless of whether volcanic activity continues or not. Besides, the presence of drift pumice from the Submarine Volcano NNE of Iriomotejima 1924 eruption (Seki, 1927) and the 1986 FOB eruption (Kato, 1988) suggests that pumice clasts from a single submarine volcanic eruption can remain on the coast for at least several tens to a hundred years. Meanwhile, the sources of many drift pumice clasts are still unknown, thus, their sources may be terrestrial volcanoes located out of the Japanese Islands and/or from unknown submarine volcanoes.

A challenge to establish a Late Pleistocene tephrostratigraphy focusing on cryptotephras within wetland sediments in Quaternary volcanic region, Central Japan

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Establishing precise tephrostratigraphic framework is essential for reconstructing volcanic eruptive histories and crucial time-markers for geochronological studies. Recently, cryptotephra studies have developed and increased the value of tephrochronology (e.g., Lane et al., 2013). However, cryptotephra detection has difficulties caused by bioturbation, secondary deposition, etc. (e.g., Davies, 2015). Especially in volcanic regions such as the Japanese Islands, secondary deposition of tephra-derived volcanic glass shards hides primary tephra fall horizons. Although Lake Suigetsu with an ideal sedimental environment preserves cryptotephra in varve sediment, volcanic glass shards of Kikai-Akahoya tephra (K-Ah, 7.3 ka, derived by caldera forming eruption) have reworked upward several thousand years after primary deposition, causing challenge to detect other cryptotephra horizons (Mclean et al., 2018).

In this study, we focus on the mountain wetlands having small catchment area because we consider size and/or relief of catchment area influence cryptotephra detection. We selected six wetlands formed by various processes, such as deep-seated gravitational slope deformation (DSGSD), landslide, and active fault, surrounding the Kanto Plain in central Japan. Then, we conducted coring, cryptotephra detection and characterization of those by determination of refractive index and major element composition of volcanic glass shards. We also obtained radiocarbon dates to cross-check depositional age.

Peaks of glass shards concentration are distinct in wetlands formed by DSGSD comparing to other sites in smaller catchment. In Chayaike Bog (Nagano prefecture) formed by DSGSD, we detected distinct two peak horizons of K-Ah and Towada-Chuseri tephra (To-Cu, 5.9 ka) with consistent radiocarbon age, although To-Cu is small amount around study site. On the other hand, in Jaishi-Okie Moor formed by active faulting and having larger catchment, volcanic glass shards of Aira-Tn tephra (AT, 30 ka) spanned several meters upward. It shows that secondary deposition processes of volcanic glass shards continued for thousands of years after primary deposition.

From these results, the secondary deposition of volcanic glass shards strongly influences cryptotephra detection. It is clarified that secondary deposition depends on size of catchment area among our study sites. Therefore, smaller catchment area is likely to be favorable for cryptotephra detection in Quaternary volcanic regions where secondary tephric materials are continuously provided.

Sediments related to meteorite collision in the Hapcheon impact crater basin, Korea

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The Hapcheon impact crater basin (HB) in the southern central part of the Korean Peninsula was formed by a meteor impact. In this study, we studied HB sediments for interpreting the meteor collision process and determined the impact pressure. A 66 m long sediment core (20HCL04) was recovered from the northwest side of the HB and 20 samples from the bottom of the core were used for petrological and geochemical analyses including X-ray powder diffraction (XRD) analysis, electron probe microanalysis (EPMA), and analytical scanning electron microscopy (SEM). Sediments related to meteor impact collision were identified, including suevites, melt breccias, and impact glasses. In particular, coesite was detected through XRD analysis, and partially and completely melted porous glasses were identified among pebbles contained in the melt breccias. These results provide evidence of a shock level > 5 meteorite collision, at a pressure of ≥ 30 Ga and will form the basis for a better understanding of the HB meteor impact collision process through further sediment studies.

Refining the Middle Pleistocene (130–770 ka) tephrostratigraphy of the Eastern Mediterranean region based on glass geochemical characterization and dating of Aegean Arc tephra deposits

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Tephrochronology has developed into an indispensable tool for precise correlation and dating of sedimentary sequences across different depositional settings and over distances of thousands of kilometers. However, the ability to use this approach in distal areas, where tephra deposits often occur as cryptotephra horizons, hinges critically on the availability of robust glass or mineral geochemical data as well as well-constrained ages for the respective tephra occurrences in proximal settings. Because such datasets have remained scarce for many volcanic sources in the Eastern Mediterranean region including the South Aegean Volcanic Arc (SAVA), we have aimed to extend and refine the tephrostratigraphy for this arc with a focus on the Middle Pleistocene (c. 130–770 ka). Two field campaigns were carried out in the western (Methana and Aegina), central (Milos and Kimolos) and eastern (Kos and Nisyros) parts of the SAVA, where over 50 pyroclastic units were sampled. A proximal tephra dataset is currently being generated using accessory mineral geochronology (combined U-Th/U-Pb and (U-Th)/He zircon dating) and major- and trace-element glass analyses of the collected samples. The newly obtained ages allow substantial refinement of previous age estimates for some eruptive units. For instance, five previously undated pumice lapilli tuff deposits from Methana, for which their emplacement was roughly constrained to the Early Pleistocene (c. 1.4 Ma), yielded Middle Pleistocene eruption ages (c. 340–430 ka) based on zircon dating. Ultimately, the refined tephrostratigraphy of the SAVA will assist proximal-distal tephra correlations in the Eastern Mediterranean region where many distal tephra layers, especially those older than 200 ka, have yet unknown origins. By extension, this will aid constructing robust chronologies for Eastern Mediterranean climate-proxy records and enable their precise synchronization.

Synchronization of lacustrine and marine sediment records in the Baltic realm using cryptotephra

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Robust and precise chronologies of paleoclimate records are a prerequisite for studies of past climatic changes. The identification of volcanic ash (tephra) deposits from past volcanic eruptions provides isochrones that allow the direct synchronization between different paleoenvironmental records. Novel methodological developments even allow the identification of macroscopically invisible volcanic ash (cryptotephra) that can be found in sedimentary records thousands of kilometres away from the volcanic source.

Here, we present new cryptotephra findings from Lake Tiefer See (NE Germany) and for the first time from the Baltic Sea (Western Gotland Basin) sediments. Relevant published tephra findings from Lake Tiefer See (Wulf et al. 2016) are summarized for comparison. The two sedimentary records are investigated within the frame of the BALTRAP project ('The Baltic Sea and its southern Lowlands: proxy – environment interactions in times of Rapid change'), aiming to improve the understanding of the impact of rapid climate change in the southern Baltic Sea region.

Throughout the mid- to late Holocene (~4.3 ka BP until AD1875), several cryptotephra horizons containing highly vesicular glass shards have been identified at both sites providing both, robust anchor points for the individual chronologies and for their synchronization. Major element electron probe microanalyses (EPMA) show that glass shard compositions range from rhyolitic to dacitic (Tiefer See) or andesitic (Baltic Sea) and correlate with the geochemical data of glass shards derived from eruptions of the Askja, Hekla and Torfajökull volcanoes in Iceland. The youngest and oldest tephra horizons from both sites contain glass shards from the Askja-AD1875 (see Wulf et al. (2016) for Lake Tiefer See) and Hekla-4 tephras, respectively. Glass shards in other tephra horizons correlate with the Hekla-3 (Tiefer See), Hekla-S, Askja A2000 and Grákolla (Baltic Sea) tephras. Based on these cryptotephra findings the Baltic Sea and Lake Tiefer See sediment records can be synchronized with each other and further European sites allowing the investigation of possible leads and lags in proxy responses to rapid climate changes.

Revisiting the occurrence and distribution of Quaternary marine Toba ash layers in the Indian Ocean

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The Toba Caldera on Sumatra, Indonesia is the host of the Young Toba eruption (~74 ka), globally one of the largest and most recognized eruptions during the Quaternary and regionally concentrated in the eastern Indian Ocean. Three older deposits (Middle, and Old Toba Tuff as well as Haranggaol Dacite Tuff) are also attributed to Toba caldera and distributed their eruption products over the Indian Ocean.

We present here the Quaternary marine tephra record from an array of 14 sites and 28 holes from deep ocean drilling programs complementing earlier work on distal to ultra-distal Indian Ocean sediment cores and terrestrial distribution data of Toba deposits. A unique set of major and trace element glass-shard compositions on 115 primary ash layers together with glass shard morphologies, core pictures and statistical analysis support geochemical fingerprinting between marine tephra layers and known deposits from Toba and five so far unidentified medium to large eruptions assigned to northern Sumatra. Additionally, zircon crystallization ages have been determined for the Haranggaol Dacite Tuff resulting in a new maximum eruption age of 1420±0.034 ka.

Tephra volumes and magma masses for the (co-ignimbrite) fallout are estimated based on the compiled marine tephra distribution that are complemented by published proximal ignimbrite volumes. For YTT the resulting tephra and DRE volume of 5600 km^3 and 3600 km^3 is in between the previous estimates. For MTT (253 km^3 DRE), ODT (1550 km^3DRE) and HDT (129 km^3 DRE), and the five additionally identified eruptions from Northern-Sumatran volcanoes, magma volumes have been determined. Overall, the new tephra record results in one large eruption every 200 kyr in the Quaternary that is derived from northern Sumatra.

Rain forest fragmentation in northern Madagascar during the past millennium - a result of intensified human impact and climate dynamics?

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With its unique flora and fauna, Madagascar is one of the earth's biologically richest ecoregions. It is known that Madagascar's ecosystems have greatly been affected by human influence during past decades, thus making it one of the most endangered ecoregions aswell. Despite the clearly visible recent changes, the exact timing of arrival of the first settlers and their impact on the environment remains a scientific debate. By analysing the sedimentary archive of Lake Amparihibe (Nosy Be Island) our research contributes to shed light on the timing of early human impact on Malagasy natural ecosystems. Several proxies i.e., pollen, fungal spore, other non-pollen palynomorphs, charcoal and diatoms combined with high-resolution sediment-physical and geochemical data were considered to reconstruct paleoenvironmental dynamics during the past three millennia. The record reveals stable environmental conditions between 3000 and 1300 cal BP. A sudden environmental change at 1300 cal BP, characterized by an increase of Poaceae pollen and charcoal particles, indicates an abrupt transformation from a highly diverse rainforest to a grassy landscape associated with fire disturbance. Increasing sedimentation rates, water turbulence and nutrient supply suggest an open landscape highly vulnerable to soil erosion. This quick shift (<10 yrs) is interpreted as a strong early human impact on the environment. After 1000 cal BP, the vegetation is dominated by a fire-disturbed forest/grassland mosaic, which is maintained until today. Since modern climatic conditions imply a potential natural vegetation dominated by rain forest, our results suggest that humans continuously shaped the vegetation during the past 1300 years. However, the scarcity of continuous records hinders a comprehensive regional synthesis. Therefore, an ongoing research effort is spent on investigating a sediment record from Lake Ravelobe (National Park Ankarafantsika) to compare both results. This might help to disentangle signals originating from human impact and/or climatic background, and ultimately detect potential (dis)similarities in climate dynamics, ecosystem responses and anthropogenic influences at the island's scale during the Holocene. This is urgently needed to understand the relationship of human influence and natural factors to current climate change and biodiversity loss, which is important to improve future conservation strategies for biodiversity hotspots such as Madagascar.

Socio-environmental interactions of the Ancient Maya in Belize from the Classic through to the colonial period: The Maya Archaeology and Palaeoecology Partnership Project

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This poster describes the approach and initial results of MAPPP, a collaborative research project between archaeologists and palaeoecologists to uncover what land use change and adaptations were adopted by the ancient Maya during periods of climate instability. The ancient Maya are sometimes characterised as a society that responded inadequately to climate change, exacerbated by poor environmental stewardship, which are both hypothesized to have brought about collapse. This view is not without controversy, and although large scale forest clearances, fire and soil erosion are observed in environmental records at the beginning of the Classic period, some researchers have demonstrated rebounding arboreal resources in the Late Classic as frequent droughts began to become apparent, suggesting that the Ancient Maya adapted their management strategies to resource scarcity and/or to mitigate climate instability. Furthermore, in the post-Classic period, the socio-environmental conditions related to changing demographies and political structures have been little explored in palaeoenvironmental research. This project uses palaeoenvironmmental records that combine a full suite of proxy indicators for past environmental and landscape change complemented by well-constrained archaeological datasets. Sites are chosen from lowland Belize, where there are few multiproxy palaeoenvironmental records, but provide several decades of archaeological research into Ancient Maya social and cultural history. These paired archaeological and palaeoenvironmental datasets in lowland Belize demonstrate socio-environmental interactions through periods of change among the Ancient Maya through to the colonial period.

The Quaternary megafauna of Apa River, Mato Grosso do Sul, Brazil

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The Mato Grosso do Sul State, Brazil, presents many paleontological sites of Quaternary age, containing fossils of the megafauna. They are found in cave and fluvial deposits as non-articulated specimens. In 2020, a new paleontological site named as Apa River in the region of Bela Vista county (Mato Grosso do Sul State), was recognized by isolated bones in fluvial sediments. This study aims to describe this new Quaternary paleontological site, focusing on the taxonomic identification of the fossil specimens and interpretation of the geological context where they occur. The basement area of this site are Neoproterozoic rocks from the Tamengo Formation, Corumbá Group, in which there are invertebrate fossils such as *Corumbella werneri* and *Cloudina*. The Quaternary fossils are found on gravel longitudinal bars along modern Apa river channel, identified as *Eremotherium laurillardi* and *Notiomastodon platensis*. The fossils indicate a short period of subaerial exposure, with features of bone surface modification, indicating that these were deposited primarily in floodplain deposits. Subsequently, with the reworking of the floodplain sediments, due to the fluvial erosion, these were deposited in recent longitudinal gravel bars. The fossils exhibit imbrication similarly to the pebbles on the gravel bars, indicating the same environmental processes. The megafauna species are related to the land mammal Lujanian time-interval of South America. These species extend the Intertropical Brazilian Region to the Central West Region of Brazil, as well as show relationships with the Pampean Region (South of Brazil, Uruguay and Argentina), throughout the Chaco plain. The fauna interchanges could explain the similarities between these two palezoogeographic regions during the Quaternary.

Tectonics, ecology, energetics and the security of food around the Isthmus of Panama

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Prior to the formation of the Isthmus of Panama, the seas of the Caribbean and Eastern Pacific were connected by a single tropical biogeographic province dominated by strong upwelling and high primary productivity. By around 3Ma, formation of the Isthmus land bridge was complete. Upwelling and high primary productivity continued on the Pacific side, but the Caribbean rapidly transformed into the nutrient-poor basin we know today. Here we trace the energetic consequences of this grand geological event, from plankton to people. We find that while primary productivity is two times higher on the Pacific coast, zooplankton biomass is a remarkable seven times greater, indicating a positive trophic amplification and corroborating predictions of greater trophic transfer efficiency in upwelling regions. This pattern continues up through trophic levels: Benthic invertebrate biomass growth is 10 times greater on the Pacific side, and shark standing biomass more than 100 times greater. The impact of these oceanic differences extend into people: Pre-hispanic human population densities were more than double on the Pacific side, and isotope and midden records suggest a greater reliance on higher trophic level marine resources than their Caribbean compatriots. Even today, more people live in Pacific regions where strong upwelling supports high fish biomass, although the industrial movement of fish and other marine resources from the Pacific to the Caribbean side, starting with construction of the Panama Canal 100 years ago, diminished the interoceanic differences in human populations. Finally, we also explored the consequences of conch harvesting over millennia in both oceans. In the Caribbean, persistent size-selective harvesting of *Strombus pugilis* resulted in significant declines in size at maturity over seven millennia resulting in a 50% reduction in protein per conch. In contrast, the closely-related Pacific *Strombus granulatus* did not change in size over the same time period despite millennia of intensive harvesting. These findings support the idea that the positive trophic amplification of highly productive regions can confer ecosystem resilience. Based on these findings, we propose that the predicted decline in tropical oceanic productivity due to climate change could erode this resilience.

Chinese Pollen Database: current status and future development

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1. Zhejiang Normal University

The construction of the Chinese Pollen Database (CPD) was started in 1994, under the framework of the BIOME6000 core project of the International Geosphere-Biosphere Programme (IGBP). During the past three decades, several versions of regional and national pollen databases of China have been built up through unremitting efforts from domestic and international palynologists and paleobotanists over generations. Nowadays, a late Quaternary pollen database of China has been established using a unified pollen taxa and standardized, calibrated dating data, including the modern pollen dataset (> 5500 sampling sites) and fossil pollen dataset (372 sites). These two datasets are being updated continuously. A new pollen dataset of China since the Cenozoic Epoch is being setting up. All of these datasets will be united to form the official Chinese Pollen Data, which will be further made public to the palaeoworld.

Regional feature of pollen R-value in China

Ms. Jie Xia [1], ***Prof. Jian Ni*** [1]
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Understanding relationships between modern pollen, vegetation, and climate is essential for quantitatively reconstructing past vegetation and climate. The R-value, a typical and traditional indicator with easy calculation, can be used to adjust the nonlinear discrepancy between surface pollen and modern vegetation. In this study, we established a dataset of 2115 pollen R-values in China collected from 898 modern pollen sampling sites and 152 pollen taxa and from 42 publications. Syntheses of these R-values revealed that: 1) Pollen R-values in China vary greatly, with the majority being stronger under-represented and a few being weaker over-represented. 2) *Pinus*, *Picea*, *Betula*, *Ephedra*, Chenopodiaceae and *Artemisia* are mostly over-represented among the common pollen taxa, while Taxodiaceae, *Corylus*, *Nitraria*, *Tamarix*, Cyperaceae, Poaceae and Fabaceae are mostly under-represented. The representative of *Castanea*, *Quercus*, Polygonaceae and Asteraceae vary depending on vegetation types. 3) Pollen R-values in China have a clear spatial geographical pattern, changing not only with pollen taxa, but also varying in vegetation types and climatic regions. Thus, the limitation of R-value, particularly the variation of the same pollen taxon across regions, must be taken into account when using R-value to characterize pollen-vegetation relationships.

Differentiating Poaceae pollen using FTIR microspectroscopy as a chemotaxonomic tool

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Due to the morphological similarity of pollen grains, grass (Poaceae) pollen can be difficult to classify below family level. Currently, discrimination between the pollen of domesticated cereal crops ("*Cerealia*"-type) and wild grasses is based on its morphology, i.e., the shape, size, and position of the pores, the texture of the exine wall, and importantly the size of the grains themselves. "*Cerealia*"-type pollen is generally larger than wild grass pollen, but there is frequent overlap between domesticated and wild grass pollen size which prevents not only accurate discrimination between wild and domesticated grass pollen but also identification at species level.

An alternative method for distinguishing between pollen of domesticated and wild grass species can be used to retrieve taxonomic signals from the pollen chemistry: spectra obtained by Fourier-transform infrared (FTIR) spectroscopy have been used for cluster (population) pollen samples and in a few cases single pollen grains. Our study uses the pollen wall spectra from acetolysed extant wild grass and domesticated cereal crops to explore how chemotaxonomy can be used as a tool for subfossil Poaceae pollen classification.

Pollen from 19 common wild grasses and domesticated cereals (widely cultivated in Europe and southwest Asia) were collected and acetolysed following standard palynological procedures and analysed as individual grains. K-nearest neighbour algorithms achieved a 77% classification success rate at species level with extant pollen, indicating the potential for chemotaxonomy to be applied to fossil pollen samples. Here we present our methodological approach and discuss the challenges of using chemical spectra when classifying fossil grass pollen to species level.

An extended chironomid training set for reconstructing New Zealand summer air temperatures

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While the number of quantitative temperature reconstructions in the Southern Hemisphere is increasing at a steady pace, many regions remain underrepresented. This is in part due to a lack of training sets to infer the relationship between proxies and climate variables. We analysed a 104-lake chironomid training set from New Zealand, an extension of an earlier 60-lake training set published in 2007 by Dieffenbacher-Krall and others.
The original model is based on the response of the lake-dwelling larvae of chironomids, or non-biting midges, to mean summer air temperatures (SmT). It has been used successfully in several studies on lake sediments to reconstruct Holocene SmT in New Zealand. However, the original model covers a relatively short SmT gradient, from ~6.5 to 15°C, and was developed primarily for use in southern New Zealand. It is therefore not appropriate to apply it in more northern parts of the country. The new training set extends the SmT gradient to 19.5°C.
We confirm that SmT is the most important variable to explain chironomid assemblage variance in the extended training set, but also find potential confounding factors, some of which correlate with SmT. We apply seven different transfer function techniques: one assemblage approach, two multivariate regression models, and four machine learning techniques. The latter are supposedly more robust in the presence of confounding variables. We discuss the differences between the seven models and apply them to a Holocene chironomid record from Lake Pupuke in northern New Zealand. We compare the performance of the original and new training set in the context of both the increased number of sites and the extension of the temperature gradient.

The updated Indo-Pacific Pollen Database (IPPD): a valuable new asset to the Neotoma Palaeoecological database

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The Indo-Pacific Pollen Database (IPPD) is the brainchild of the late Professor Geoffrey Hope, who gathered pollen records from across the region to ensure their preservation for future generations of palaeoecologists. This noble aim is now being fulfilled by integrating the IPPD into the online Neotoma Palaeoecological Database, making this great compilation available for public use. Here we explore the database in depth and suggest directions for future research. The IPPD comprises 226 fossil pollen records, most postdating 20 ka, but some extending as far back as 50 ka or further. However, many of the records contain few samples or have fewer than 5 chronology control points, such as radiocarbon, luminescence or Pb-210 for the younger sequences. 83.6% of the records are Australian, with a fairly even distribution between the different Australian geographical regions, with the notable exception being Western Australia, which is only represented by 3 records. The records are also well distributed in modern climate space, the largest gap being in drier regions due to preservation issues. Average sedimentation rates counted as years per cm are quite low for many sequences, meaning each cm of sediment represents a fairly low number of years, with 61% of the records having a rate of less than 50 yr/cm. However, the average rate for the whole IPPD is 60 yr/cm, with the highest rate by geographical region occurring in arid Australia. The lowest rates are from the Western Pacific and Maritime SE Asia. Overall, Australia has a higher rate than the rest of the Indo-Pacific region. This could be due to the targeting of longer records, which tend to have a higher rate, or it could be due to relatively lower precipitation leading to lower biological activity in the lakes and wetlands that represent the vast majority of sites. The IPPD offers many exciting research opportunities, with one possibility being the examination of human impact on regional vegetation, contrasting first human arrival and colonialization, and another the assessment of rates of vegetation change during the Holocene.

Using plant functional traits in paleoecology: a calibration study from Arid Central Asia.

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The necessity of accurate past climate reconstructions for climate modelling is a key issue in (paleo)ecology. Especially, dryland such as Arid Central Asian deserts may spread in the next decades in surrounding steppes due to aridification. Several methods already exist to convert pollen in quantitative climate (transfer functions) and biome (biomization). However, these methods are impeded by numerous biases, which could be overcome by current breakthrough in plant functional response to climate understanding.

Few past pollen studies attempt to merge plant functional traits with pollen samples in order to reconstruct paleo-trait cover and functional vegetation dynamics. However, this approach has not been tested using modern samples. Especially, since the taxonomic resolution used in ecology is not the same as the one used in pollen studies (usually family or genus pollen identification), whether the phenotypic space of extant vegetation is consistent with that derived from pollen modern samples remains an open question.

Here, we tested the performance of combining paleoecology and plant functional ecology to validate the use of pollen to infer the phenotypic space of past vegetation. The pollen surface sites from Arid Central Asia (n = 2393) have been extracted and the pollen-types have been used to aggregate traits (height, leaf area, leaf nitrogen, seed mass, specific leaf area and stem specific density from TRY, BIEN and GIFT databases). Then, the community-weighted mean (CWM) traits have been calculated using the pollen fractional abundances. These pollen-CWM traits have been compared with the vegetation-CWM (n = 21347). Finally, both have been related to current climate parameters.

The preliminary results of this study show that the trait values aggregated by pollen-types respect the same plant economic spectrum than observed in botanical taxonomic resolution. Moreover, it validates the use of pollen as equivalent of vegetation plots to calculate the CWM. It also appears that the scheme of aggregation between the pollen-type and botanical species is not strongly impacting the CWM trait response to climate. These results open a new avenue to use plant traits in paleoecological study in order to reduce climate reconstruction biases and to improve pollen-biomization scheme for past vegetation reconstructions.

Automated pollen analysis: the state of play

Dr. Katherine Holt [1]
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Since the 1960's, partial or complete automation of pollen microscopy has provided a tantalising prospect for the labour-intensive discipline of palynology. Since then, progress has occurred in fits and starts, typically occurring in step with advances in computing power, which have facilitated developments in the fields of machine learning and image processing. Until recently, most attempts at automated palynology, or at least those captured in the literature, could only really be regarded as proof- of-concept, in that they demonstrated that it was possible to successfully identify pollen, or indeed other microfossils using the chosen methods. But few studies were working with problems at a 'real world' scale. For example, the majority of studies involved a limited number of taxa, which were not representative of the likely diversity expected in paleoecology samples.

In recent years, we have arguably entered a new phase of automated pollen analysis, again driven by advances in computing capability and digital image technology. Specifically, the ability to produce very large sets of digital images, quickly and cheaply, has paved the way for Deep Learning Convolutional Neural Networks (DLCNNs) to come to the fore. DLCNNs differ from earlier artificial neural networks mainly in the number of hidden layers they use and the way they represent features in images. So far, they have shown considerable promise, in that they have been applied to classification problems of a much greater diversity than previous attempts, AND have delivered strong results. Automated systems also show considerable promise in discriminating morphologically cryptic taxa which have so far been too challenging for human analysts to distinguish through purely visual methods alone.

But despite these advances, we are still not at the point where we are actually realising the dream of using an automated system to significantly reduce the amount of time spent on the microscope in order to generate data for palaeoecology. What limitations, then, remain? Arguably, the most significant challenges lie in dealing with non-pollen objects, broken/deformed pollen, clumped pollen, and pollen that is not yet known by the trained system. These issues, and more, will be explored in this presentation.

pastclim: an R package to easily access and use paleoclimatic reconstructions

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The recent development of continuous paleoclimatic reconstructions covering hundreds of thousands of years paved the way for a large number of studies from disciplines ranging from paleoecology to conservation, archaeology to population genetics, macroevolution to anthropology, and human evolution to linguistics. The downside to this process is that (paleo)climatic data are stored in large and complex file formats, and they can be challenging to handle for scholars unfamiliar with them.

Here we present pastclim, an R package facilitating the access and use of paleoclimatic reconstructions (https://evolecolgroup.github.io/pastclim/index.html).

It currently gives direct access to two such datasets, covering respectively the last 120,000 and 800,000 years, and a vignette provides instructions on how to include additional ones. We are expecting the number of datasets available to increase in the following months.

The package contains a set of R functions to quickly and easily recover the climate for time periods of interest either for the whole world or specific areas, extract data from locations scattered in space and/or time, retrieve time series from individual sites, and manage the ice or land coverage, offering a handy platform to include the climate of the past into existing or new analyses and pipelines.

Making spatial pollen modelling FAIR: Multiple Scenario Approach in QGIS

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Spatial reconstruction of vegetation has been one of the main goals of pollen analysts since the dawn of the discipline. Approaches centred around algebraic models of the pollen-vegetation relationship have made considerable progress in recent decades, resulting in reconstruction methods such as the Landscape Reconstruction Algorithm (LRA) and Multiple Scenario Approach (MSA). Spatial pollen modelling is currently a niche activity within the wider discipline of pollen analysis, due to the complex nature of the models and the closed, available-on-request approach to software and code. This approach is understandable, since complex models can be subject to misuse due to the user not completely understanding the model assumptions and input requirements (treating the model like a "magic black box").

In order to realise the potential of spatial modelling within the field of pollen analysis, pollen modelling software packages need to be available for wider use. As an educational tool they would allow students to experimentally explore connections between landscape and pollen assemblages, which is essential to learning to interpret pollen data. As a research tool the models can be used not just for a full reconstruction of past landcover, but also to explore thought experiments or inform site selection. Reconstruction outputs, especially in the form of maps, also have a wider outreach value, as maps convey information in a more intuitive way compared to traditional pollen diagrams, which makes them suitable for communication with non-specialist audiences.

I therefore present a new software package for the Multiple Scenario Approach, written in Python for QGIS, that adheres to the FAIR (Findable, Accessible, Interoperable and Reusable) principles. Keeping the data and software FAIR allows spatial pollen modelling specialists to check the work of the users and allows users to look inside the "magic black box", while also making spatial pollen modelling more widely available, which will be beneficial for underfunded research facilities, commercial and independent researchers, and students and teachers.

Expanding capacity and support for Quaternary vertebrate data curation and analyses

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Reliable inference of the drivers of and impacts from biotic responses to climate change require high-quality data. The FAUNMAP database was the result of a multi-institution vertebrate data curation effort that catalyzed a generation of impactful research focused on North American Quaternary mammals. Key early findings stemming from this database included the widespread occurrence of no-analog species associations, the influence of climate on small mammal communities across the Quaternary, and substantially reduced Holocene mammal diversity relative to previous time periods. In 2008, FAUNMAP data along with the North American Pollen Database were joined to form the core of the Neotoma Paleoecology Database. The Neotoma-FAUNMAP constituent database is a living rather than static repository: originally contributed data are preserved with a stable DOI, but datasets can also be refined and updated as new information becomes available. The Neotoma framework and common data format has provided researchers with the ability to update taxonomies and nomenclature, and to link records to other data types such as pollen, plant macrofossils, ostracodes, diatoms, coleoptera and isotopic data from bones and teeth in a seamless way, facilitating analyses of whole-ecosystem responses to climate over the Quaternary.

Here, we describe new updates to both the vertebrate data in the Neotoma Paleoecology Database and to the underlying Neotoma data model. Data model changes include the ability to curate specimen-level data, linked to repository IDs, which facilitates associations between specimens, radiocarbon dates, isotopes, ancient DNA, and the broader site context. These data model changes have spurred updates to site-level data and improved data coverage. We also describe progress towards automatically capturing new radiocarbon dates, new specimens, and new sites using the automated text and data mining tool xDD. We use these new and refined data to undertake a comprehensive update to the age models for North American vertebrate sites, and provide the foundation for a new generation of analyses targeted at understanding community assembly processes through time.

FOSSILPOL: The workflow to process global palaeoecological data of fossil pollen for large-scale synthesis

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The study of biodiversity and ecosystem patterns through time and space requires large-scale syntheses of palaeoecological datasets. The data preparation for such syntheses must be transparent and reproducible. Until now, a guide for interdisciplinary data analysts on how to standardise large data compilation of palaeoecological records is missing. Without guidelines on the explicit assumptions that underlie palaeoecological data and their analyses, appropriate use of the data is jeopardised and follow-up analysis can be undermined.

We present FOSSILPOL as a workflow to efficiently process global fossil pollen data to create a standardised project-specific dataset compilation. The goal of the FOSSILPOL workflow and corresponding R-package called R-fossilpol is to facilitate such compilation in a comprehensive and reproducible way, ready for multi-record and multi-proxy analyses at macroecological scales. With our workflow documentation and website, we outline the most crucial decisions needed to standardise palaeoecological data, specifically using fossil pollen data. User-defined criteria are project-, and research-question dependent and are condensed into one overview file for easy reviewing and reproducibility purposes. Such criteria will maximise the quality of the dataset compilation and facilitate discussions among interdisciplinary experts.

Using palaeoecological data with solid knowledge of the data's strengths and weaknesses – and how to overcome them – is a great tool for researchers in any field to address research questions that can ultimately help decision-makers, conservation organisations, and governments understand biodiversity and ecological processes

Given the increasing amount of open-access data across large spatial and temporal scales, our workflow offers an easy way to prepare reproducible palaeoecological compilations for synthetic and cross-disciplinary analyses with macroecological, biogeographical, and palaeoecological perspectives.

Forecasting Fossils: Combining Paleontological and Contextual Attributes for Predictive Models in the Eastern Narmada Basin, India.

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Narsinghpur district, Madhya Pradesh, situated in the Narmada valley is known to be one of the most fossiliferous areas in this region. Since initial discoveries this area has been known as the home of fossils of multiple vertebrate species such as Antilope cervicapra, Boselaphus tragocamelus, Proboscideans, Trionyx gangeticus, Hexaprotodon sp, and Equus namadicus, etc. many of which have now become extinct. The discovery of microvertebrate species has also been made in this region. While the preserved fossils are not rare, most of the fossil occurrences are represented by individual elements having varied extents of preservation. Narsinghpur district holds the unique position of being between the Satpura and the Vindhya mountain range and along with Narmada, is home to many of its tributaries. Interestingly, field surveys and newly built predictive models both suggest that obtaining fossils from areas near the rivers such as river beds, river banks, and terraces hold a high probability. Localities near these areas such as Barmaan Ghat, Devakachar, Umeriya, Gawari, etc. have yielded multiple fossils, and the geological contexts of the discovered fossils have been studied in detail. The geological contexts at Narsinghpur district contain combinations of boulder conglomerate, cemented sandy gravel, yellow or pinkish cross-bedded sand, breccia gravel, and reddish silty clay. A predictive model of potential fossil locations was initially created using a weighted combination of environmental and geological variables (slope, vegetation, soil type and character), This was combined with a MaxEnt model trained using known fossil locations to predict likelihood using the same variables but without biasing the model towards investigated areas. In this paper, we would like to explore the possible correlations between concentration of fossils and their extent of preservation, and geological factors such as: proximity towards specific geological features, the AMSL height of the locality, and the lithostratigraphy present at the site. We posit that finding such patterns will expose a quantitative effect of geological phenomena on fossil preservation and eventual discovery. With the help of the predictive model, we hope to predict fossil occurrences in currently unexplored regions of the world, directing on-ground human effort more efficiently.

Selecting sites for pollen analysis

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Pollen analysis is a very widely used technique for reconstructing past land cover, and thus inferring human activity, climate change and a range of other ecological and environmental processes. The power of pollen analysis comes in part from the importance of plants in ecosystem formation and in part from the wide dispersal of pollen grains, which enables sedimentary systems to record not just local environments but also traces of the wider environment. Interpretation of the pollen record is challenging due to taxonomic limitations (multiple related plant species can produce indistinguishable pollen grains), variations in the amount of pollen produced by different plants, and variations in dispersal mechanisms? relating to plant growth habits and reproductive strategies. Model-based approaches have improved our understanding of the spatial signal reflected by pollen assemblages and provided means of extracting quantitative estimates of past landcover from pollen data, using approaches such as the Landscape Reconstruction Algorithm or the Multiple Scenario Approach, and have considerable scope for improving communication and collaboration between palaeoecologists, archaeologists and ecologists, vital for addressing major societal challenges.

In order to take full advantage of the new understanding offered by models of the pollen-vegetation relationship, modelling should be fully integrated into the pollen analyst's work flow, rather than something reached for once the data collection is complete. Simulation based on the landscape of interest can be used to make an informed choice of sediment core location, by exploring the sensitivity of different possible sampling points to the hypothesised changes of interest, and to inform the size of pollen count needed to be able to detect a specific change, should it have occurred, with confidence. This paper presents a recommended workflow for using simulation to maximise the relevance of data retrieved from months or years of laboratory work both through informing site selection and through contributing to interpretation and reconstruction of past landcover.

SIG in Palaeontology: Biome dynamics through the Pleistocene

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Biomes are the ecological and evolutionary units in which we can divide the Earth attending to their biological community and physical environment. Large-scale properties and distribution of terrestrial biomes depend primarily on climatic factors, along with soil type, water availability and environmental disturbances, among others. These factors have affected biomes in the past and keep doing so nowadays. Thus, shifts in climatic factors drive changes in the distribution of biomes, which fluctuated through geologic time. Nevertheless, our knowledge of past biomes configuration is scarce. Understanding the fluctuation of biomes' distribution through time is important to frame palaeontological and evolutionary studies of species in relation to their environment. One way to assess the distribution of these biomes in the past is through geographic information system (GIS) tools, which together with the recent availability of fine-scale climate data allow us to model climate at both temporal and spatial scales.

In this work, we modelled past biomes' distributions to explore how climatic changes affected them during the Pleistocene, a period of marked climatic fluctuations. We compared glacial and interglacial periods, typical of the Quaternary climatic cycles. In particular, we modelled biomes distribution during the Last Glacial Maximum (LGM) and the Last Interglacial (LIG). This allowed us to see how the world biomes geographic areas expanded or fragmented according to the climatic fluctuations. We found that glaciations contracted and fragmented tropical biomes, whereas colder biomes expanded. In the interglacial phases, however, tropical biomes were favoured whilst colder and arid biomes were contracted and fragmented.

Reconstructing the past: 14C dating and stable isotopes of archaeological mollusc shells from Vale Boi (Portugal).

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Mollusc shells are often found in archaeological sites, given their great preservation potential and high value as a multipurpose resource. The site of Vale Boi (Algarve, Portugal) is a well-known Upper Paleolithic site representing the earliest recorded modern human occupation in southwestern Iberia, as attested by the Early Gravettian remains dated to c. 32 ka cal BP. This site has a long stratigraphic sequence spanning from the early Gravettian to the Proto-Solutrean, Solutrean, and Magdalenian. Previous studies found evidence of multiple human occupations at this site, proving that it was most likely a seasonal residential camp with a combination of exogenous and regional cultural traits and intense and diversified use and processing of available resources, including mollusc shells. Furthermore, there was an intense presence of inland and coastal foraging, hunting, and processing of various types and sizes of prey, possible processing of edible plants, as well as the production of various lithic and bone tools, ornaments and art, including abundant shell beads. The presence of numerous mollusc species spans the site's different layers, proving the continued use and importance of mollusc shells as a resource throughout the stratigraphic sequence of Vale Boi. Being situated between two different environments: the Mediterranean and Atlantic coasts, this site could give us insight into the ecological and socio-cultural dynamics of different populations that inhabited the Southwestern part of the Iberian Peninsula during the transition from Middle to Upper Paleolithic. This underlines the importance of creating a secure chronological determination, which, combined with paleoclimatic and archaeological data, can give us a better understanding of the socio-cultural, technological, and ecological behaviour at the site.

To do this, we tested and applied four different pre-treatment methods for ^{14}C dating of mollusc shells and performed stable isotope measurements for climate reconstruction. Determining which of these methods is the most reliable for ^{14}C dating and combining it with isotope measurements will result in the possibility of constructing precise chronologies and paleoclimate scenarios, allowing for a better interpretation of the ecological and cultural variability at the Middle to Upper Paleolithic transition at Vale Boi.

Single-grain OSL dating of the Neanderthal site of Axlor (Biscay, Spain): cultural and environmental change in southwestern Europe from MIS 5 to MIS 3

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The cave site of Axlor (Biscay, Spain) preserves one of the most informative Middle Palaeolithic (MP) records for the North Atlantic Iberian region, though its age remains poorly known. Key findings at the site include Neanderthal remains, marked faunal changes through time, micro-Levallois assemblages overlain by typical Quina, and original osseous tools and hearth structures. Here we use single-grain optically stimulated luminescence (OSL) and single-grain thermally-transferred OSL (TT-OSL) dating of sediments to improve the age constraint of Axlor's MP succession (levels N–B). Our new ages are consistent with (i.e., older than) the previously published terminus ante quem 14C ages for the site (>42.9 cal ka BP), and suggest the sequence accumulated between ~100 ka and ~50 ka, during a critical period in Neanderthal history. Our results indicate that major faunal and technological turnovers occurred towards the end of MIS 5, potentially correlative with broader environmental and climatic changes. Additionally, our new ages indicate that the Axlor's Quina record is one of the oldest in Spain. Comparisons with neighbouring sites point to complex regional chronologies and development for this particular behaviour, though detailed correlations with other MP sequences remain difficult due to their poor chronological attributes. The present study highlights the important role that single-grain optical dating can play in elucidating the broader evolution of the MP across the region.

Cividate Camuno (Brescia – north-west Italy) – hunter gatherers between the Late Glacial era and the beginning of the Holocene

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In the Alpine area, during the last glaciation, in the large valleys such as that of the Adige the glaciers filled the valleys reaching a thickness of up to a thousand metres. These areas were, during the coldest times, completely uninhabited, most recently around 24-20,000 years ago. After the Last Glacial Maximum, the environmental and climatic conditions began to change and humans returned to the valleys. North-eastern Italy – east of Lake Garda – has provided numerous traces of these early recolonisations, but the same cannot be said for the areas to the west of Lake Garda (Lombardy and Piedmont) where only a few faint traces of early Holocene human presence are known.

The site at Cividate Camuno (Valcamonica – Brescia), on the valley floor at an altitude of 275 m asl, with multiple occupation levels datable to the Late Glacial and early Holocene, is unique in north-western Italy. At the site were found an inhabited area with a Palaeolithic "hut" and an Early Mesolithic level.

The archaeozoological analyses of the Late Palaeolithic levels (18,066-15,576 years cal BP) show different hunting strategies from those of the Mesolithic level (10,180-9590 years cal BP), reflecting environmental variation and, hence, changes in locally available prey.

The Late Palaeolithic occupation thus represents the first trace of a human presence in the western Alps since the glaciers reached the Po Plain, at least 15,000 years earlier. The members of these human groups were pioneers in an uninhabited and hostile environment who, thanks to their technical knowledge, were able to adapt to such difficult environmental conditions. They hunted ibex, which lived on the valley floor, and the deer that returned to the areas from which the glaciers receded.

The Mesolithic occupation provides evidence of the subsequent adaptation of human groups to an environment that had changed thanks to the retreat of the glaciers to higher elevations and, on the valley floors, had left room for the spread of wooded areas that hosted deer, roe deer and wild boar – the favoured prey of these Mesolithic hunters.

Organic Material from the Ancient Great Wall of China as a Climate Archive: Environmental Change and Archaeological Conservation

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The Great Wall of China is one of the most recognizable world heritage sites. What is perhaps less well known, is that the iconic brick walls built during the Ming Dynasty in the 15th Century AD are only a small part of an extensive system composed of fascine and rammed-earth walls, beacon towers, and fortifications that expanded to the western imperial frontier as early as the Han Dynasty in the 2nd Century BC. Plant materials used in the construction of these wall segments and beacon towers contain untapped potential for revealing paleoclimatic and paleoenvironmental changes of northwestern China over the last two millennia. For the first time, we characterize the molecular preservation and stable carbon and nitrogen isotope compositions of AMS-dated common reeds (*Phragmites*) collected from ancient Great Wall fascines in today's Gansu and Xinjiang using a combination of chromatographic techniques and isotope analyses.

Using these novel archaeological samples, we quantitatively demonstrate that ancient Great Wall reeds retain excellent molecular preservation and illustrate the potential of using this common construction material as an archive for paleoclimatic and archaeological proxies. Both the molecular distribution of plant waxes and bulk carbon isotope compositions indicate that the ancient reeds were harvested from local sources and illuminate site-specific environmental records and differential rates of environmental change across northwestern China. Meanwhile, extremely heavy nitrogen isotope values show variability in the use of fertilizers around large population centers. Overall, our study represents the first attempt to reconstruct the source and local habitats of Great Wall building materials that contain information on the impact of climate change on local environmental settings. Additionally, this work demonstrates the potential for paleoenvironmental reconstructions applying molecular and stable isotope methodologies to any ancient structure that was built, at least partially, using locally-sourced organic materials.

Investigating the effect of UV radiation on Pinus spp. pollen-chemistry in field conditions

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Ultraviolet radiation has effects on the biosphere at the level of genes, species and ecosystems. Despite the significance of UV-B for ecosystems functioning and individual plant fitness, the response of plants to UV radiation remains poorly understood. One of these responses is the production of *para*-coumaric acid to protect cell contents from the adverse effects of UV. *Para*-coumaric acid is an important compound in the pollen grain wall and is theorized to act as a "sunscreen" for pollen grains and the genetic material within. Nevertheless, the relationship between dose and response of para-coumaric acid to UV in pollen grains is not fully understood. Plant responses to UV radiation are mediated by environmental factors and by interacting regulatory and stress-induced pathways in the plant. UV exposure experiments have shown contradictory results from dose-responses and stress responses to UV damage, which indicate that multiple mechanisms are involved in regulating a plants response to UV exposure. For pollen chemistry it is important to untangle the response of para-coumaric acid production to not just UV-B, but also in combination with UV-A and PAR.

We present the first results from field experiments to help understand the chemical response in pollen to UV-radiation. In the field experiment three filters were attached to branches of *Pinus* uncinata trees to shield the pollen from i. only UV-A radiation, ii. both UV-A and UV-B radiation, and iii. permit all UV radiation. After maturation of the pollen, chemical methods are used to identify the composition of the pollen (IR/Raman spectroscopy, and mass spectrometry). This field experiment aims to identify the effects of natural UV-B radiation on pollen-chemical composition in general and on *para*-coumaric acid in particular. Our results are the first systematic field experiment which manipulates incoming solar radiation and its effect on pollen chemistry. These results will further our understanding of chemical responses to UV radiation and represent an important contribution to the ongoing effort to develop a UV-proxy based on pollen chemistry.

The role of the Moonmilk speleothem in hypogeal archaeological sites

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The moonmilk is a speleothem of microbial origin, usually formed by nanofibers of calcium carbonate, and found in karst caves. We discovered the presence of the moonmilk in the Etruscan hypogeal tombs of Tarquinia, a unique case of a biogenic activity resulting in protective rather than damaging a cultural heritage site. In fact, after 2,500 years, the Etruscan mural paintings in these hypogeal tombs were found well preserved under the white patina of the moonmilk. To study this phenomenon, we previous analyzed the calcite nanofibers of 5 tombs, together with their microbial communities. A deep investigation of the geology of this site was also conducted to unravel how the co-evolution of microorganisms and the rock contributes to this calcium carbonate deposition.

The Etruscan tombs were carved in a yellow calcarenite, called *macco*, rich in calcium, produced 5 million of years ago, during the Pliocene. In Italy, a similar calcarenite rock is found in Puglia, in the south of Italy. This region is rich in karst caves and many of them harboring important archaeological remains. One of the most famous sites is the Lamalunga cave, near Altamura, Puglia, where a complete Neanderthal skeleton was discovered in 1993. We had the opportunity to take samples from this cave and we will present a comparative analysis of the calcarenite rocks and the microbial communities of the moonmilk from Tarquinia and Lamalunga archaeological sites, to investigate the geomicrobiological situation, as a part of a preservation project of archeological karst caves, to be ready, in the near future, to identify criticisms due to climate changes.

Genetic structure of the population reflect the Pleistocene glaciations: the case of the humid- and cold-tolerant root vole Alexandromys oeconomus (Rodentia, Cricetidae) in Poland (Central Europe)

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Contemporary distribution of species in many areas of the globe is the result of phenomena occurring in the Pleistocene. During this period there were significant changes in the climate and extensive areas were occupied by ice sheets. Their presence not only limited the range of species, but also influenced the shape of the landscape, and thus the contemporary habitat system that determines biodiversity pattern. The purpose of the presented research was to find out how the landscape of eastern Poland, formed as a result of subsequent Pleistocene glaciations: Sanian 1, Sanian 2, Odranian, Wartanian and Vistulian, affects genetic differentiation of a species. The hypothesis was tested by analyzing the DNA of the root vole *Alexandromys* (*Microtus*) *oeconomus* (Arvicolinae, Rodentia) - boreal and hygrophilous species. Samples of tissue were collected from 439 vole individuals at 33 locations in different post-glacial landscape zones. Based on analysis of 12 microsatellite loci and the 908 bp of cytochrome b sequences (mtDNA), the genetic structure of M. oeconomus in the landscape zones of Polish Lowlands was determined. The results of the study showed that longitudinal variability of the relief in the area of eastern Poland (resulting from different limits of Pleistocene glaciations) and the related specific configuration of hydrogenic habitats are reflected in the genetic differentiation of the root vole. It was found that the best living conditions for this species persist in large habitats with a high degree of connectivity - in swampy river valley systems of central eastern Poland, shaped mainly during the Wartanian Glaciation. The lowest genetic variability was found in the most mature, southern zone, the original relief of which was formed during the oldest glaciations (Sanian 1 and Sanian 2). It indicates that the most difficult conditions of life for the root vole occur there. And this is due to a completely different arrangement of habitats preferred by this species. The relationships found may also become an indicator useful in explaining the geological history of the region.

A needle in the haystack: Tracing and quantifying the sea ice diatom and IP25-producer Haslea spicula in environmental DNA samples

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One of the most striking effects of climate change is the continuing loss of Arctic sea ice in the last decades. Past sea-ice conditions are poorly understood particularly prior to the satellite era, and there is a significant gap in our understanding of sea-ice variability on geological timescales. Therefore, there is a need to develop new reliable proxies that can capture sea ice variability. Sea ice harbors a vast biodiversity of unicellular microorganisms with fine-tuned evolutionary traits. Sedimentary ancient DNA has recently been shown to be a promising tool for reconstructing past marine biodiversity. However, most of the species that are truly specific to sea ice only account for a small fraction of the biota, are understudied, and for DNA approaches references are largely missing in existing DNA databases. A few species of the diatom genus *Haslea* produce a source-specific molecular compound (a lipid biomarker named IP_{25}) that can be preserved in the seabed for millions of years. However, the environmental and physiological conditions controlling the production of IP_{25} are not well understood and thus detecting the species itself might provide more robust reconstructions. In classical diatom microfossil assemblages and in DNA metabarcoding studies, the IP_{25} producers are usually not detected. Here, we explore the potential to detect and quantify past occurrences of *Haslea spicula* in sedimentary ancient DNA records. Several strains of diatoms from Hudson Bay in the Canadian sub-arctic were isolated into monocultures, among them three strains of *H. spicula*. The strains were confirmed to produce $IP_{25.}$ We isolated a molecular signal from the *rbc*L gene and designed a beacon specific to *H. spicula* that can be used to trace and quantify this species in marine sediments using a droplet digital PCR approach. DNA was isolated from ~ 100 surface sediment samples in Baffin Bay and Northeast Greenland, as well as from locations outside the seasonal sea-ice regime to compare with sea-ice concentrations and biomarker profiles. We validated the approach by applying it to a dated sediment core record from Northeast Greenland.

The main periods and environment factors of coastal sand dunes developments in the East Asia during the mid to late Holocene

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To confirm coastal sand dune development processes and periods in the west coast of the Korean Peninsula, this research examined the depositional age using optically stimulated luminescence (OSL) dating for three dunes including Taean Chollipo, Seocheon Dasari, and Gochang Sabanri dunes. The results were then compared with those of previous research. Sedimentation rates were calculated for the three dunes, and their development periods were classified through statistical analysis that included data from previous studies. According to the results, the coastal dune development during mid to late Holocene was divided into five main periods: <0.1, 0.2−0.5, 1.2−2.0, 2.5−3.2, and 5.5−6.5 ka. These periods correlate with the periods global cooling of the Holocene by ice rafted debris (IRD) records. The development of coastal dunes is mainly affected by the global cooling events and the enhanced East Asian winter monsoon. In addition, human activity increases also contributed to the development of the dunes recently.

Unravelling the evolution of a complex strandplain (Western Port, Australia)

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Strandplains, or prograded barriers are worldwide distributed, coastal landforms that provide a palaeoenvironmental record within a sequence of successive, mostly linear ridges and intervening swales. While many of these landforms have been studied intensely, those with variable terrestrial morphologies are often poorly understood due to their complexities and uniqueness. One complex strandplain stretches along the main entrance of Western Port on the southeastern coast of Australia. This morphologically complex barrier was formed as a function of its somewhat sheltered position and orientation in relation to sporadic swells and tidal circulation. LiDAR-derived topography shows highly truncated and asymmetrical ridges both across and along the plain. These uncommon morphologies are associated with an intricate hydrodynamic circulation subject to sporadic storms approaching at a sharp angle to the shoreline that eliminate a significant part of the sedimentary record but also redistribute vast quantities of sand to the downdrift shoreline, and a large and variable sandy bank that undergoes intense sediment movement. Using optically stimulated luminescence (OSL) dating of quartz, it was possible to unravel the rather unique and entangled development of this strandplain. An age of around 2,600 years for the innermost dated ridge, located about halfway across the plain. Significant erosion of the ridges' record occurred on the western side of the barrier between 2,600 and 700 years ago and between 600 and 240 years ago while ridges on the eastern side were preserved. Sediment characteristics suggest that the type of material provided for barrier accretion remained the same throughout the late-Holocene. An evolutionary model is proposed to decipher this barrier's formation and contribute to the sediment budget of Western Port.

Boulder barricades in northern Finnmark, Norway

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Spectacular boulder barricades are widespread along the Barents Sea coast of Finnmark, Norway, similar to those found along other parts of the Norwegian coast, the Baltic Sea and in eastern and Arctic Canada. Not particularly well studied in terms of their formation, boulder barricades are nonetheless important Arctic coastal landforms that play an important role in arctic pond and wetland development. The spatial distribution of the northern Finnmark boulder barricades, classified into distinct types, will be presented alongside an analysis of the processes and conditions responsible for their formation, including sea ice, currents, wind, waves, coastal physiography, and changes in relative sea-level, past and present.

Misremembered natural heritage: a case for integrated ecologies

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The significance of geohistory, including oral history, is commonly overlooked in the practical management of today's natural landscapes. In Australia, conservation policy is largely embedded in the physical sciences, with targets directed at the preservation or restoration of Indigenous or early-European ecological benchmarks. For example, federal and state environmental legislation strives to protect "Endangered Ecological Communities" (EECs). These purportedly represent remnants of naturally occurring groups of plants, animals and other organisms. In many cases, however, classifications of EECs are made in the absence of any long-term data, making it unclear as to whether the "natural" community that is being protected is indeed "natural". Further, it precludes an understanding of past Indigenous land-use practices, making it challenging to manage landscapes appropriately to account for the range of past disturbances that are crucial for shaping ecosystem expression and resilience dynamics. We use multidisciplinary geohistorical data to map the long-term socio-ecological history of freshwater wetlands that were once a key landscape feature of Australia's biggest city, Sydney, and today provide habitat for EECs protected under State and Commonwealth legislation. Our results clearly demonstrate that what is being conserved today is remarkably different from the pre- and early- European landscape, highlighting how quickly we can come to "misremember" landscapes of the past. This showcases the importance of long-term, multidisciplinary data from both the social and physical sciences for developing evidence-based conservation policy. More broadly, it highlights flaws in post-colonial approaches to environmental management.

Combining palaeoecology and system dynamics modelling to inform management and restoration in the Cape Floristic Region, South Africa

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Effective restoration and sustainable management of ecosystems requires knowledge of the extent of anthropogenic impact over recent decades and centuries, and identification of management options that can restore ecosystem services. Combining palaeoecological reconstructions of past changes with modelling techniques allows stakeholders to understand landscape history and explore the effects of different management interventions and future scenarios.

This transdisciplinary study investigates the variability plant biodiversity and drivers of change by combining palaeoecology, stakeholder engagement and system dynamics modelling. Palaeoecological data (fossil pollen, spores, charcoal) were used to define the historical range of variability in vegetation, herbivory and fire. Stakeholder collaboration was used to identify feedbacks between environmental (climate) and anthropogenic (fire, herbivory) drivers, a process that underpinned the development of causal loop diagrams and a system dynamics model that was used to explore the implications for restoration and management.

The 1300-year-old palaeoecological record from Elandsberg Private Nature Reserve, in the Cape Floristic Region of South Africa shows a decrease in plant biodiversity driven by increasing grazing and exacerbated by increased fire during agricultural and conservation activities. Specifically, intensive grazing and burning from the 1950s led to an increase in *Elytropappus* (renosterbos) that persisted after the area was declared a nature reserve, with continued high levels of grazing and burning. The associated system dynamics model successfully simulated this transition. Running the mode with various combinations of fire and herbivory suggest that it will be difficult to restore the ecosystem to its former state, even if fire and grazing are reduced.

The study shows the potential of integrating palaeoecological work with system dynamics modelling to engage with stakeholders and guide effective restoration and sustainable management of social-ecological systems.

Towards integrating palaeoecological and traditional knowledge to preserve the Ethiopian Ericaceous belt.

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The Afromontane biome is a globally important biodiversity hotspot, supporting the livelihoods of more than 200 million people by providing essential natural resources and ecosystem services. The biome occurs between ca. 2000 to 4000 m asl including the Ericaceous belt (EB) above 3200 m asl, The EB is one of the most fragile Afromontane communities, dominated by *Erica arborea* and *E. trimera* stands. It is especially and critically endangered by rising temperatures and unpredictable rains, rapid population growth, and agricultural expansion. Conservation efforts in the EB have traditionally aimed to limit burning practices in protected areas, despite evidence that fire has been used as an agropastoral tool on the African continent for tens of thousands of years and current research suggesting that elimination of burning may result in high-severity fires.

The EB is one of the ecosystems where fire has long been used by people and local knowledge and paleoecology therefore need to be considered in conservation planning. Here we show how information on long-term ecosystem dynamics from the Ethiopian Ericaceous belt in the Bale Mountains National Park (BMNP) can be combined with interviews to pastoral communities of the Arsi Mountains National Park (AMNP). Both protected areas present similar vegetation and human activities, but AMNP receives less tourism, and traditional cattle and farming management is more widespread. Combining both perspectives will produce an integrated scenario on past vegetation change, as well as a better understanding of local attitudes about the environment in the Ericaceous Belt.

The evidence from paleoecology and local community knowledge suggests that past burning patterns in the Ethiopian highlands occurred under fire-conducive climates and seasonal biomass accumulations. We also inferred that intermediate fire return intervals, between 4 to 30 years, may have sustained a continuous Erica cover. The results suggest that a total fire ban will lead to important changes in EB structure and high-severity fires, given current increasing temperatures and population. As still many questions remain, we plan to continue our paleoecological research in the Arsi Mountains by examining other lake-sediment records as well as starting new calibration studies including the local knowledge and communities perspectives.

Response, resilience, and recovery of Tasmania's endangered Pencil Pine using a multi-archive palaeoenvironmental record

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The Tasmanian Wilderness World Heritage Area (TWWHA) in Australia is home to globally significant and highly valued flora, with ancestries in the Gondwanan supercontinent. Anthropogenic climate change is shifting baseline conditions and increasing pressures on long-lived palaeoendemic tree species directly via increasing temperatures and aridity across southeast Australia and indirectly via increased lightning-ignited wildfires. During the summer of 2016 over 80 wildfires were ignited across the Central Plateau (Tasmania/Lutruwita) decimating stands of Gondwanan taxa in TWWHA severely threatening core refugia of extremely fire-sensitive palaeoendemic conifer *Athrotaxis cupressoides* (Pencil Pine).

In the Northern Hemisphere, fire-sensitive species with demographic traits similar to Pencil Pine (i.e., long-lived (>1000 years), slow-growing and poorly dispersed) are becoming increasingly climatically stranded as envelopes of optimal climate conditions rapidly migrate with altitude and latitude. This increases their vulnerability to loss or extirpation when left exposed in areas where climate is unfavourable for post-fire regeneration.

Despite efforts to manage threatened Tasmanian ecosystems, the long-term impact of climate change (and other factors) on the resilience of these systems remains poorly understood. Thus, there is a lack of understanding of how to apply the most efficient, impactful and cost-effective management strategy. Here, there is a need to develop a deep, long-term understanding of these long-lived ecosystems to execute well-informed land-management strategies for their future preservation.

This project applies palaeoecological and geochemical analyses on organic sediments extracted from lake and bog sites across the Central Plateau (Lutruwita) coupled with high-resolution palaeoclimatological speleothem analysis performed on a stalagmite collected from a proximal cave site. This research will provide a detailed multifaceted understanding of how historical species composition, fire regime and moisture variability has influenced the response, resilience and post-fire recovery of Pencil Pine dominated systems across the Central Plateau throughout the Holocene (ca ~11.7 kyrs to present). Such findings aim to facilitate a holistic understanding of how best to target management efforts to preserve highly threatened Pencil Pine, and other long-lived fire-sensitive ecosystems in the wake of the climate crisis.

Ostracod shell chemistry as an independent measure of shallow lake eutrophication?

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Shallow lakes provide extensive ecosystem services and are ecologically important non-marine resources, supporting a diverse flora and fauna. However, worldwide lakes are threatened by environmental degradation (e.g. nutrient pollution from agricultural fertilizers). The restoration of these environments is critical for future biodiversity, resilience to climate change, the provision of ecosystem services, and is legally binding under the EU Water Framework Directive (WFD). To meet the requirements of ‘good ecological status’, lakes must not be significantly altered from pre-defined ‘reference conditions’, which are the conditions expected in the absence of anthropogenic impacts. Palaeolimnology offers a method to define reference conditions for effective restoration. However, existing approaches (e.g. diatom transfer functions) for reconstructing nutrient enrichment are problematic due to their indirect approach that involves major assumptions. Multi-proxy studies attempt to disentangle drivers but fail due to circular reasoning and a lack of an independent measure of phosphate (P). Ostracod (small bivalved crustaceans) shells, however, calcify using elements taken from the lake water, providing a direct reflection of lake-water concentrations. Here, we present results of ostracod shell chemistry (P/Ca) calibrations from natural and controlled environments to reconstruct palaeo-P concentrations. Robust independent palaeo-P concentrations are a potentially significant advancement in the ability to 1) set reference condition P concentrations for shallow lake restoration targets under the WFD and 2) to predict the effects of future climate change on freshwater biodiversity.

Climate and human impacts on montane forests in the Simmental near Boltigen, Northern Swiss Alps

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Global change significantly impacted life on Earth over the last few decades and negative effects such as species losses or community collapses are anticipated to increase in the future. One of the most pressing challenges associated with global change is assessing potential ecosystem responses to global warming as well as land-use. Mountain ecosystems, such as the European Alps, are particularly vulnerable to global change due to the presence of endemic and highly specialized species along steep climatic and ecological gradients. Understanding long-term vegetation responses to past climate change and anthropogenic disturbance is critical for assessing future community and ecosystem responses to global change. In the Alps, fundamental uncertainties about former vegetation dynamics and human impact still exist. Novel well dated, multi-proxy reconstructions are needed to better understand the interactions between climate, vegetation, fire and land use.

We cored two neighbouring montane mires in the Simmental, Northern Swiss Alps, Chutti (941 m a.s.l.) and Chrome (995 m a.s.l.), which will be analysed for pollen, spores, stomata, microscopic charcoal and plant macro-fossils. The Late Glacial vegetation history of these mires was studied by the palaeoecology pioneer Max Welten since the 1930's, but the Holocene vegetation history remains unexplored. A recently discovered Bronze Age hilltop settlement in very close proximity to the mire Chutti shows the potential of the sites in studying the impacts of land use on local vegetation. Moreover, not much is known about the ecosystem history of the intermediate elevations in the Simmental and generally the Swiss Alps. Here, we will use different statistical techniques, like ordination analyses, cross-correlations and biodiversity estimations to analyse our data and quantify the impacts of climate, land use, fire and browsing on vegetation dynamics. The results will be crucial in contextualising recent ecosystem changes and are needed to plan appropriate restoration strategies under global change conditions in order to avoid biodiversity and ecosystem service losses.

Understanding ecological change at popular inshore reef settings in the Whitsundays, Great Barrier Reef, Australia

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Historical photographs of reef environments have been contentiously used in recent years to highlight the decline of the Great Barrier Reef since European settlement. Yet the presence of low levels of living coral and high macroalgal cover may represent natural senescence or a transitional stage following recent disturbance, rather than a degraded state. By taking a multidisciplinary approach that combines geomorphology, palaeoecology, geochronology and palaeoclimatology, our aim is to provide a comprehensive understanding of coral community change for inshore reef flat environments from the popular Whitsundays region, a major tourist destination that has been repeatedly photographed since c.1890. Elevation surveys of Bramston Reef, Stone, Hayman, Daydream and Saddleback Island conducted during periods of lowest astronomical tide in 2012, 2021 and 2022, reveal all reef crest environments depicted in the historical photographs to lie well below the upper limit for coral growth [i.e. ±20 cm mean low water spring tide level], suggesting vertical accommodation space is not a limiting factor for reef health. Uranium-thorium dating of surficial dead coral assemblages collected from these locations revealed mortality to have occurred before modern ecological surveys began (with the exception of Hayman Island), with ^{230}Th ages bracketing the timing of historic acute disturbance events such as major flooding and cyclones. Modern benthic photographic surveys suggest coral recovery is taking place at all locations except Stone and Daydream Island, with both remaining at <5% coral cover for the entire survey period. We attribute this to be a result of low structural complexity and long-term chronic disturbance, respectively. These results provide a preliminary baseline understanding of coral community change over the past several centuries with which to appropriately assess the current and future health of Whitsunday reef systems.

What is ‘natural’? Stand-scale pollen and plant macrofossil analyses of remnant broadleaved woodlands in Scotland offer insight for restoration

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Extending the timescales over which we understand the scale and drivers of change is vital in efforts to restore more naturally functioning and resilient ecosystems. Our research focuses on remnant ‘ancient’ semi-natural broadleaved woodlands in Scotland which have been designated for conservation. With woodland cover considerably lower than the European Union average (18.5% versus 38% of land area), Scotland has ambitious plans to expand woodland cover and restore more favourable ecological conditions. Ancient woodlands are often considered to be the natural ecosystem ‘baseline’ against which woodland management strategies are conducted. However, plot-based long-term woodland monitoring is typically limited to timespans shorter than single generations of long-lived tree species – meaning management and restoration efforts may be based on inappropriate reference conditions.

In this paper, we demonstrate that palaeoecological data can provide records of woodland dynamics on a spatial and temporal scale that is highly relevant to ecologists and site managers. Pollen and plant macrofossil analyses of peat deposits from forest hollows are used to provide highly localised records of vegetation change over the last c.1500 years, thus spanning multiple woodland generations. ‘Stand-scale’ insights into compositional and structural changes, and their drivers, are more closely comparable to long-term woodland monitoring than more traditional landscape-scale palynology. Our approach also focuses on sub-canopy layers which are often masked by the canopy forming trees. Plant macrofossil analysis is used to compliment pollen analysis and heighten taxonomic resolution. Micro and macro-charcoal analyses and coprophilous fungi are utilised to assess disturbance from fire and herbivory. Robust chronologies are provided by radiocarbon (^{14}C) based Bayesian age-depth models.

Collectively, these techniques are used to explore the effects of grazing, burning and management on woodland composition, species diversity, function and resilience. We critique associations between woodland continuity and conservation value and investigate whether woodland biodiversity has changed over time. Potential shifts in baselines are identified and we highlight the importance of human activities as agents of woodland change and survival.

From early Medieval forest fires and livestock foraging to the current phase of global warming (Valmalenco, Italian Alps): hints for rewilding and nature conservation

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An increasing array of observations shows that European mountains are experiencing a period of intensified environmental transformation. However, the timing, rate and amplitude of these changes are only partly detectable by monitoring contemporary ecosystem dynamics. Too many ecological alterations occurred since Medieval permanent settlements, overriding part of the pristine (i.e., pre-Neolithic) ecosystem structure. More recent trajectories in land use promoted by industrial revolution were ultimately redirected, due to a fast abandonment since the Second World War and the last forty years of amplification in Global Warming. We suggest that land use changes observed since the mid- to late-19th century may provide one of the tipping points connecting earlier baselines with the contemporary active pressures on mountain ecosystems. This requires focusing on the timing, the rate of change, and the mutual interaction between climate and land-use variation with a decadal to centennial scale resolution.

We discuss the contribution of paleoecology and historical ecology to assess contemporary dynamics through a case study on the last 1750 years of forest fires and livestock foraging in Valmalenco that combines co-registered microbotanical data, charcoal analyses, sediment lithology, mineral nutrients, modern pollen deposition, dendrochronological information, and documentary written records. The following ecological processes concern future strategies of nature conservation and rewilding: (i) slope denudation connected to fire events in the late Roman age; (ii) early medieval forest fires in pristine mixed conifer forest with *Abies alba*, nowadays eradicated; (iii) Late Medieval expansion of the foraging area for pastoralism, timberline depression and expansion of larch parklands, and preservation of old-growth larch individuals; (iv) Industrial Age and the post- World War II abandonment of traditional land uses and (v) the last forty years of increasing trend in Global Warming.

Disturbances mediated European mountain forest diversity and stability

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Recent studies have shown that latitude is responsible for Europe's primary long-term diversity gradient, controlled by climate and human impact combined, the latter being more prominent in recent millennia. The diversity trends may also vary regionally depending on the biogeographical regions. The disturbance is essential for maintaining or even increasing ecosystem diversity in many systems, therefore it is crucial to reconstruct its past dynamics. The European mountain forests dominated by spruce and beech have been affected by many threats in recent decades, increasing their vulnerability of loosing biodiversity and stability. These ecosystems may serve as a long-term laboratory to study these threats.

We reconstruct long-term diversity trends on the longitudinal gradient in central-eastern Europe across several biogeographical regions. We use data from multiple proxies (pollen, plant, and insect remains). Primarily, we use richness in fossil taxa as an index of their alpha diversity. To uncover ecosystem diversity's complex mechanism, we also reconstruct beta diversity for standardized time slices. To better understand the diversity dynamics, we reconstruct disturbance regimes using charcoal data, pollen-based disturbance indicators and insects. Moreover, we also calculated the stability index of the ecosystem based on change point analysis of dominant taxa and their variability assessment.

Our results support the previous findings of increasing diversity gradient throughout the middle and late Holocene and reaching higher values at the gradient towards the east. We observe much higher fire activity and overall disturbance in the east than in the west despite increasing trends in beech representation in the forests in both regions and relative forest stability. Climate may be one of the reasons behind such a trend, and the trend itself could also help maintain the higher diversity in the east. Beta diversity shows first the homogenizing trends in ecosystem development shifting to more diversification of ecosystems amplified by intensifying human impact. We conclude that moderate human activities may be beneficial in maintaining forest stability and diversity, but the observed accelerating trend in disturbance and deforestation during the Anthropocene may imply enormous threats to mountain forest diversity in the near future.

Peatland restoration based on a landscape (palaeo)ecological system analysis (LESA): the case of Aamsveen, eastern Netherlands

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This study illustrates the relevance of a spatiotemporal landscape ecological system analysis (LESA) for the recovery and sustainable management of a complex, dynamic rare wetland ecosystem. The Dutch Aamsveen lies in a glacial basin in the Dutch-German border area. It consists of remnants of a cross-border raised bog and a lagg with degrading species-rich basiphilous plant communities. Farther west, the Glanerbeek drains the footslope at the edge of the basin and adjacent lagg. For the Netherlands, this is a rare wetland ecosystem and an important Natura 2000 area, but it is threatened by ongoing degradation. A spatiotemporal LESA, including extensive palaeoecological research, showed the fundamental role of the interplay between infiltrating acid bog water that gradually acquires basic cations from the underlying base rich sediments as it flows laterally towards the lagg, where it seeps up, and the (lesser) influx of base rich surficial groundwater from the ice-pushed ridge in the west. Anthropogenic disturbance of this interplay has led to serious system degradation. The results of this LESA, in which palaeoecological, geophysical, hydrological and ecological data were combined, served to develop an integrated management plan at landscape level, instead of habitat level plans as is usual in the context of Natura 2000. This research is therefore a great example of integrating paleoecology in nature conservation and restoration ecology.

Validating future land use change scenarios using long-term perspectives from lake sediment records: approaches to restoring freshwater total phosphorus conditions

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Phosphorus (P) supply to freshwater systems has accelerated over the last few centuries due to land use intensification and exacerbated landscape degradation, causing a global deterioration in water quality and ecosystem health. Reversing this trend requires management decisions that prioritise stabilising the landscape and re-establishing natural ecosystem functioning via land use change, that will ultimately work towards restoring 'pre-disturbance' lake water total P (TP) conditions.

Export coefficient and process models can be used to estimate how such changes will impact on catchment P cycling. However, it is not possible to determine whether the modelled scenarios represent realistic responses of P dynamics to land use change without comparison to suitable analogues. Lake sediment geochemical records of historical catchment P export can provide an empirical framework for validating past (and thus future) model predictions.

Here we present a critical comparison these methods using case studies from the Shropshire-Cheshire Meres, a collection of lakes with a long history of human activity; clear impacts on P cycling are visible from the Neolithic and there is evidence that cultural eutrophication occurred as early as the Iron Age. We compare outputs from export coefficient and processes model outputs with lake sediment records of Holocene landscape P export and land use change. Using this combined approach, we find that it may not be possible for lake water TP to return to 'pre-disturbance' levels, as present-day atmospheric loadings, including lateral contributions from adjacent catchments, are too high. However, the modelling suggests that it may be possible to achiever 'good' TP concentrations if the direct contribution from cattle and the human contribution via septic systems are removed. The modelling approach combined with the long-term perspective from the sediment record provides a robust basis for exploring management options for reducing lake water TP concentrations.

Geoarchaeology of the Younger Dryas in the Northern Great Basin, USA: The View from the Paisley and Connley Caves

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In the northern Great Basin, the Younger Dryas Cold Event (YDCE) occurred between 12,900–11,600 years ago (cal yr BP) and is marked by cold temperatures and wetter conditions which resulted in pluvial basins being filled with shallow but permanent lakes or well-watered marshes or meadows. Consequently, the region experienced rapid changes in plant and animal communities that subsequently affected late Pleistocene and early Holocene human population organization and settlement dynamics in the region. The abrupt shift to cold and wet climates appears to have positively affected Paleoindian foragers, but a lack of well-dated and stratified archaeological sites hinders our ability to adequately test this hypothesis and place early foragers into broader discussions of human-environment dynamics. Thus, there is a need for high-resolution studies of deposits containing evidence of occupation spanning this key late Pleistocene to early Holocene transition, especially those aimed at shedding light on the types of deposits, characteristics, and features that define the YDCE. Research at the Paisley and Connley Caves since 2015 has revealed stratified deposits with rich cultural assemblages spanning the LP/EH transition, providing a unique opportunity to study Paleoindian lifeways during this key climate transition. Our results suggest that YD-aged deposits at the Connley and Paisley Caves were altered under periglacial conditions, consequently exhibiting weakly and moderately developed cryogenic structures. Soil micromorphology revealed cryogenic fabrics and features, including banded and lenticular fabrics, silt caps, vesicular pores, and ice blades. Coupled with high-resolution mapping of cultural materials and radiocarbon dating, this paper incorporates geoarchaeological data and outlines one approach for disentangling human-environment dynamics occurring at the end of the Pleistocene, thereby providing a framework for understanding similarly-aged sites in the northern Great Basin.

Late Pleistocene and Holocene climate variability in inland Iberia. Stalagmites from Los Casares cave (Guadalajara, Spain).

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In the central area of the Iberian Peninsula there is a great general void in the study of speleothems, being limited to Castilla y León the vast majority of works carried out. In this paper we present a paleoclimatic reconstruction during the Late Pleistocene and Holocene, comprising part of the Marine Isotope Stages (MIS) 3-1, from two stalagmites from Los Casares cave (Guadalajara, Spain) based on U/Th dating and stable isotopes. The Cueva de los Casares is the most important site with Palaeolithic rock art in the centre of the Castilian Plateau and contains a key archaeological deposit for the understanding of the human occupation of the last Neanderthals in the interior of the peninsula. Due to the presence of this important site in the cave, it has been possible to correlate the regional paleoclimatic variations recorded in the stalagmites with the anthropic activities in the cave during the Middle and Upper Palaeolithic in inland Iberia.

Multiproxy evidence for the Late Pleistocene environmental stability in the Lesser Caucasus

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Located at the crossroads of out-of-Africa migration routes, the Lesser Caucasus served as a natural passage, the so-called Trans-Caucasian corridor, that enabled hominin dispersal out of the Levant and into the rest of Eurasia during the Pleistocene. Additionally, it has been long debated whether the region persisted stable environment throughout the last glaciation and served as a refuge for ancient human groups and temperate biota.

To deepen our knowledge of the Late Pleistocene environmental conditions and test the refugium hypotheses we endeavoured a multidisciplinary exploration of Karin Tak cave, Lesser Caucasus. In particular, we examined biostratigraphic changes in the site by looking at the taxonomic composition of acquired samples using traditional paleontological/zooarchaeological approaches and novel molecular methods of faunal identification including the use of collagen fingerprinting and aDNA metabarcoding. Father, to zoom into the region's environmental conditions, we applied stable carbon and oxygen isotope analyses to faunal tooth enamel dated between ca. 48,000 and 22,000 cal BP.

The obtained results allow us to suggest that cold and arid MIS 2 conditions did not cause a dramatic change in the regional environment, and during the Late Pleistocene the cave was close to the boundary between arid subtropical and humid climate regions (with the latter supporting forests), a pattern similar to the current environment of the site.

Let it burn! A micromorphological investigation of the Kropfsberg mine (Tyrol, Austria) and its history of use from the late Roman period until modern times

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The Kropfsberg hill is a dolomite outcrop located next to the confluence of the Inn Valley and the Ziller Valley, in North Tyrol (Austria). The mound is dominated by a castle built from 1280 CE onwards, which destroyed most of the prehistoric traces of occupation on its summit. Indeed, Kropfsberg was inhabited from at least the Early Iron Age and favoured for its advantageous position within the rich fahlore mining district of Schwaz-Brixlegg. Starting from this period, the mound itself was exploited for its copper minerals, while during the Middle Ages and the Early Modern period mining activities shifted primarily towards the extraction of silver. Over time, the prehistoric use of the fire-setting technique to quarry the hill led to the formation of impressive domed cavities in this hard dolomitic rock.
Excavations conducted in 2020 exposed for the first time the stratigraphic sequence of this man-made cave and led to a surprising discovery. Indeed, what was thought to be exclusively a mining site revealed the existence of a phase of use—dated to the late Roman period—with ritual connotations. The deposits of this phase are strikingly different from the other mining sediments, not only because of the abundant charcoals and animal bones, but especially because of the deposition of hundreds of votive coins.
In this talk we will focus on the results of the micromorphological study conducted on sediment blocks collected from the stratigraphic sequence of the cave. Aim of the investigation was not only to define the nature, temporal scale and possible cyclicity of the firing episodes that occurred in occasion of ritual ceremonies, but also to characterise the complex history of use of the Kropfsberg mine over time. For this purpose, of primary importance was the reconstruction of the many natural and anthropogenic processes that led to the formation of the sequence and to the preservation of this extraordinary infill, which would have hardly survived in an unsheltered context.

Early evidence of human presence in Western Europe beyond 1 Ma: new dating results from Alto de las Picarazas site (Valencia, Spain)

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Our understanding of early human dispersals in western Europe sits on a very fragmented archaeo-palaeoanthropological record based on a limited number of Early Pleistocene localities widely scattered throughout the continent. Evidence older than 1 Ma is even more scarce and restricted to a few sites, mainly located on the northern Mediterranean margin.

In this context, the Alto de las Picarazas site (Valencia, Spain), discovered in 2007 during the construction of wind turbines, can bring additional key information about these little-known early human occupations, as far as timing, palaeoenvironmental conditions or behavioural/cultural aspects. The site is made of a series of fissures and cavities in a limestone formation filled with fossil-bearing brecciated sediment. Successive excavation campaigns performed at Cavity 1 revealed a ca. 6 m thick sedimentary infill in which four stratigraphic layers were identified (named I to IV from top to bottom). In particular, the stratigraphically lowermost layer (IVb) yielded fossil remains from large and small mammals in association with a few lithic artefacts.

A magnetostratigraphic pilot study showed a dominantly reversed polarity for the bottom part of the sequence, correlating the deposits to the Matuyama Chron (> 0.77 Ma). The study of the rodent assemblage, and especially the presence of *Allophaiomys ruffoi*, suggests that unit IVb is biochronologically older than Barranco León and Fuente Nueva-3 (Spain) and coeval with the fauna from Venta Micena (Spain) and Pirro Nord (Italy).

In order to refine this first chronological estimation, several fossil teeth were collected from the lower layers and dated by means of Electron Spin Resonance in combination with Uranium-series (U-Th). The samples were processed following the most advanced analytical procedures: various enamel samples were collected from each tooth, while several laser ablation ICP-MS U-series profiles were carried out across dental tissues. The environmental dose rate was evaluated through laboratory and *in situ* measurements. Our numerical dating results, in combination with additional magnetostratigraphic data, confirm not only the Early Pleistocene antiquity of the lowermost unit IV, but also an age > 1 Ma, making Alto de las Picarazas one of the oldest dated archaeological site in W Europe.

Spatial and temporal distribution of major tree and shrub taxa during the Cantabrian Magdalenian

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Recent excavations ascribed chronologically to the Cantabrian Magdalenian cultural complex have provided a huge number of well-dated palynological and anthracological records, allowing to reconstruct, not only the main climate features and the human-vegetation interactions, but also the spatial distribution of tree and shrub taxa. Overall, the Lower Magdalenian (20000-17000 cal yr BP) sites are defined by an steppe landscape with scattered conifers like *Juniperus* sp. or *Pinus* sp., xerophilous shrubs like *Prunus* or *Hippophae rhamnoides* and heaths (*Erica* sp.), whereas western Cantabrian Range coastal archaeological records denote high amount of Fabaceae (*Cytisus* sp., and *Ulex* sp.) and *Betula* sp., probably linked to particular substrate affinities. During the Middle Magdalenian (17000-15500 cal yr BP) charcoal and pollen assemblages include diverse mesic taxa, especially *Salix* sp., *Quercus* subg. *Quercus* and *Sorbus aria*, although steppe elements and conifer trees/shrubs continue being the main landscape elements. This pattern, however, is reversed during the Late Magdalenian (15500-12700 cal yr BP) when palaeobotanical assemblages reveal a sharp increase in broadleaved tree taxa (*Quercus* subg. *Quercus*, *Corylus avellana*, *Alnus* sp., *Sorbus aria*, *Fraxinus* sp.) in response to the increase in humid and milder climate conditions. It is worth noting that some records have also addressed the survival of Mediterranean trees and shrubs (e.g., *Quercus ilex/coccifera* type, *Laurus nobilis*, *Arbutus unedo*, *Rhamnus/Phillyrea* or *Pistacia* sp.) in topographically favorable coastal and mid-altitude shelters, which long-term presence is explained by complex adaptations to edaphic, topographic and microclimatic factors.

Examining sediment infill dynamics at Naracoorte Cave megafauna sites using multiple luminescence dating approaches

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The Naracoorte Cave Complex (NCC) represents Australia's richest Pleistocene megafaunal fossil locality, preserving extensive palaeontological and palaeoenvironmental sediment records spanning the last 550 thousand years (ka). Relatively little is known about the long-term sediment accumulation dynamics of NCC solution pipe cavities, and many of the megafauna-bearing infill deposits remain undated as they lie beyond radiocarbon and OSL age ranges. In this study, we assess the suitability of using 'extended-range' luminescence dating signals (single-grain TT-OSL, multi-grain pIR-IRSL) for improving existing chronologies at six Late and Middle Pleistocene NCC sites. We additionally undertake multi-site examinations of NCC sediment infill dynamics using published chronological datasets.

Replicate luminescence dating comparisons performed on 22 sediment infill samples reveal consistent OSL, TT-OSL and pIR-IRSL ages over the last 300 ka, and broader agreement with independent and semi-independent age control (U–Th and ESR ages). Modern analogue samples collected from above and beneath active solution pipe entrances confirm adequate OSL, TT-OSL and pIR-IRSL signal resetting down to sufficiently low residual levels. Collectively, the results of the modern analogue and (semi-) independent dating comparisons demonstrate the potential usefulness of extended-range luminescence techniques for dating NCC deposits that exceed conventional OSL dating limits.

A detailed luminescence dating examination of solution pipe dynamics is performed at Smoke Tortoise Cave (SMT), which reveals a complex accumulation history focused on the marine isotope stage (MIS) 9 and MIS 7 interglacial complexes, as well as the MIS 8e interstadial. The SMT case study highlights that NCC solution pipes are not simply associated with short-lived opening and sediment accumulation events, but may involve multiple, discontinuous deposition episodes and reactivation events.

An initial multi-site examination of all published NCC infill chronologies (n=70) appears to suggest statistically significant, preferential solution pipe development during relatively wet parts of interglacial or interstadial cycles. This non-uniform infill age distribution implies that NCC solution pipe dynamics may have exerted taphonomic biases on fossil accumulation, which should be taken into consideration when reconstructing long-term palaeoecological histories from NCC solution pipe cavities.

Pyrotechnologies of Middle and Later Stone Age foragers in Malawi – a micro-contextual approach with controlled heating experiments

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The use and control of fire has shaped who we are today, and virtually all human populations depend on fire both biologically and culturally. While much research has focused on biological aspects and on when or where humans first started to use fire, less is known about how the use of fire evolved as a technology in early hunter-gatherers. Excavations in the rockshelter sites of Hora-1, Mazinga-1, and Kadawonda Complex in the Kasitu Valley of northern Malawi have exposed late Pleistocene and Holocene anthropogenic deposits containing MSA and LSA archaeological assemblages. Human remains have been retrieved from all three sites, with the apparent use of fire for ritual interment practices during the LSA. Thin section analysis of the archaeological deposits has revealed abundant soil aggregates and combustion-derived materials, including well-preserved plant ashes. In our EU-funded project, MicroAsh, we investigate this rich combustion-record to obtain a better understanding of pyrotechnological practices, which will enable us to make more detailed interpretations about the types of activities carried out at these locations.

We use micromorphology and μFTIR to study (1) site formation processes, (2) the relationship between fire use and palaeoenvironments, (3) variability in the use of fire for ritual and subsistence practices through time, and (4) site-use intensity. The production of reference samples of ash and heated soil through controlled burning experiments plays an important role in our approach and is aimed at reconstructing fuel sources and burning temperatures. Preliminary results indicate that wood ashes likely make up bulk of the combustion materials, rather than sedges or grasses from the nearby riverbanks. By exploring different microarchaeological techniques to study these human-made fire residues, we hope to contribute to a better understanding of pyrotechnologies during the MSA and LSA, and related aspects of human behavior such as rituals and foraging strategies.

Exceptionally Rich Late Neanderthal Occupation of Sesselfelsgrotte in the Franconian Jura: Different Behaviour or Different Preservation?

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A large body of research from the Swabian Jura (SW Germany) has resulted in the interpretation that Neanderthals in this area were outplaced by H. sapiens ca. 43 ka ago and that they used caves and rock shelters less intensively than their successors. These interpretations are in contrast with findings from Sesselfelsgrotte in the nearby Altmühl Valley (Franconian Jura, SE Germany). This rock shelter site, excavated in the 1960s-80s, contains multiple Neanderthal hearths, suggestive of a use of the shelter different from the Swabian sites. Sesselfelsgrotte also exhibits a rich fossil record of 14 Neanderthal remains, belonging to at least three different individuals, including a potential infant burial, while Swabia so far yielded only one, poorly contextualized, Neanderthal bone. Do these dissimilarities reflect differences in late Neanderthal forager behaviour, or are they the result of differential site preservation? These questions cannot be answered with the data available from the excavations, as detailed geoarchaeological studies at the site were not carried out.

In this poster, we present preliminary results of "SHARP - Testing hypotheses on the transition from Neanderthals to H. sapiens at the Palaeolithic site of Sesselfelsgrotte", funded by the National Geographic Society (NGS-96087R-22). In this project, we aim to (1) determine whether the Altmühl Valley served as a refugium for late Neanderthals, (2) investigate the cause of their rich record in this valley, (3) reconstruct late Neanderthal fire use, (4) explore the morphological and genetic similarities with other late Neanderthals and possible admixture with early European modern humans, and (5) test previous hypotheses on the arrival of H. sapiens in Central Europe.

Cutting-edge geoarchaeological methods are the backbone of this project and will address key taphonomic issues to clear up potential analytical biases and ambiguities in the reconstruction of late Neanderthal and early sapiens behaviours in SW Germany. Geoarchaeological investigations within SHARP will provide a multi-scale framework (from microscopic to regional) to help integrate new geochronological data and results from lithic, faunal, microfaunal, archaeobotanical, paleoanthropological, paleogenetic, and stable isotopic analyses.

Tackling site formation at the archaeofaunal assemblage of Level 3 from Cueva Des-Cubierta site (Pinilla del Valle, Madrid) using spatial taphonomic approaches

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Paleolithic assemblages preserved in cave deposits are taphonomically complex due to the effect of alternating hominin and carnivore occupations and the impact of post-depositional processes. Quantifying the effect of post-depositional disturbance, identifying the factors operating in these cave deposits, and defining individual depositional events is, however, essential in order to make accurate interpretations of hominin behavior.

Cueva Des-Cubierta cave is a site located in the upper valley of the Lozoya River, in the Spanish Central System. It is an 80 m long roofless cave with a zig-zag-shaped narrow gallery (2-4 m wide) in which several archaeopalaeontological levels were deposited. Level 3 is a 2 m thick clast-supported gravel deposit formed over a speleothem dated in the MIS6a, and deposited over a cold period according to the pollen and micromammal record (probably MIS4 or the earlier MIS3). This level contains a Mousterian lithic assemblage, an archaeofaunal record dominated by cranial remains of large horned ungulates, and abundant fire-affected materials, and it has been interpreted as a symbolic place.

In this study, we use spatial taphonomy to examine whether the cave deposit exhibits any spatial variation in its vertical section regarding post-depositional disturbance caused by typical karstic processes, such as water flows or gravitational processes. Spatial statistical approaches are applied to a number of taphonomic variables, including specimen size, taxon, anatomical part, bone shape, and bone composition.

Overall, the archaeological deposit shows a low degree of disturbance. Bone shape and composition types are uniformly distributed, suggesting a similar low degree of post-depositional impact caused by water flows throughout the deposit. There is a marked contrast in the spatial distribution of cranial and postcranial remains, which could be suggesting a differential treatment of cranial and postcranial elements by Neanderthals.

Further spatial statistical examination of other taphonomic attributes, such as fire-affected remains, as well as

the analysis of spatial associations between bone and lithic remains, will shed further light on the role played by Neanderthals in this faunal accumulation. This study also shows that spatial taphonomy constitutes a powerful tool that can be used to unravel palimpsests in cave deposits with complex depositional histories.

Quaternary paleontological records in Sardinia caves

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Within the Mediterranean realm, Sardinia is one of the most important sites for paleontological studies, with an international scientific value. The fossiliferous heritage of this island was early recognised since the first zooarcheological investigations. This paleobiodiversity is related to its geological history that records over 500 million years of sedimentary successions. Separated from Southern Europe in the Tertiary, its insularity has determined significant evolutionary changes of its fauna with respect to the mainland. For this reason, Quaternary fossils in Sardinia are characterised by a few taxa with an high endemic faunistic content. Many of these paleontological archives have been preserved in cave deposits. In fact, about 10% of the Sardinia area is composed of karst rocks (most of which are limestones, dolostones, and small spots with marbles outcrops) and over 4,500 caves have been explored. The main morphological feature of these karst systems is an horizontal arrangement of its underground cave passages that makes possible to preserve relatively thick sedimentary deposits. As poorly affected by recent tectonic deformation and erosive processes, Sardinian caves are excellent continental archives of Past Global Changes and document an extremely interesting evidence of Quaternary fauna records. Several paleontological studies have been addressed to the description of these cave faunistic remains and to establish their evolution over time. In this study an extensive literature review of the taphonomic researches on Quaternary fossil vertebrates in Sardinia caves is proposed, focusing on their chronological constrain with the aim of a better characterisation of the paleoclimatic and paleoenvironmental conditions of Western Mediterranean climate during the Quaternary.

What can marine shells tell us about climate change and human behaviour? A contribution to the SPHeritage Project

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The SPHeritage Project (MUR grant: FIRS2019_00040, P.I.: M. Pappalardo) investigates how human population have responded to major sea-level variations and climatic changes that affected the Liguro-Provençal Mediterranean coast over the last 400,000 years.

This project proposes a multidisciplinary approach that includes geomorphology, geology, stratigraphy, palaeontology, and archaeology. Both non-invasive and microinvasive methods were applied to materials of geo-archaeological relevance.

Here, we provide a preliminary review of the mollusc remains from both marine and archaeological deposits recovered at Barma Grande and Prince of Monaco caves (Ventimiglia, Italy).

The present study represents a major contribution to the SPHeritage project, providing information on the biodiversity of coastal marine ecosystems and its evolution due to environmental and ecological processes, and how human presence have influenced these processes.

As most of the local deposits were removed by former archaeological excavations since the end of the nineteenth century, we combined analyses of materials preserved at museums and specimens still preserved in situ.

A methodology combining taxonomy and taphonomy was applied to better understand the nature of the deposits. A systematic review of the old nomenclature was conducted, allowing a re-reading of the assemblages from a modern perspective.

Interglacial MIS5e is well documented in the studied marine natural deposits due to the presence of typical warm water "Senegalese" fauna (e.g., *Thetystrombus latus*) along with a heterogeneous malacological assemblage including small gastropods and very worn beach shells. The characterization of this malacofauna as a whole will enable a reconstruction of the original paleoenvironmental and paleoclimatic conditions.

Otherwise, the above anthropic layers are dominated by human selected species, mainly *Patella rustica* and *Patella ferruginea*. Although nowadays its range is restricted to few Mediterranean areas, Neanderthal populations largely exploited *P. ferruginea* for dietary purposes.

Preliminary analysis of cave features and archaeological evidence at Grotta dei Pipistrelli (Matera, southern Italy)

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In karst settings, the study of stratigraphy and the interpretation of the site formation processes are the keys to understanding the diachronic changes and long-term patterns of human evolution, but also a matter of discussion concerning culture and behaviour in the past, especially when considering archaeological deposits whose accumulation is mainly the result of natural processes. At Grotta dei Pipistrelli cave (Matera, southern Italy), where a Middle Palaeolithic to Bronze Age human occupation was attested, an integrated multidisciplinary approach combining geological, geomorphological, and geoarchaeological analyses of cave features and deposits was applied to tackle these issues. The cave opens on the western side of a deeply incised fluviokarst canyon, at the contact between the Upper Cretaceous Apulia carbonate units and the Plio-Pleistocene Calcarenite of Gravina Formation. A recent topographic survey indicates that the cave plan reaches a total extension of 225 m, including a main sub-horizontal wide conduit, a smaller branch towards its end, and two secondary passages which form an orthogonal network of galleries. A collapsed doline, obstructed by siliciclastic sediments from the top surface, overlays the end of the main conduit. A significant amount of guano covers the cave floor. In the main conduct, an archaeological deposit with carbonaceous levels and fine-grained siliciclastic sediments is currently the object of petrographic and microstratigraphic characterisation (micromorphology) and luminescence dating. The topographic survey allowed us to measure and map several types of cave-rocky features, including ceiling pockets and cupolas, condensation-corrosion channels, pendants, wall convection niches, smooth walls, and replacement pockets. Secondary cave minerals and weathering products were sampled on the cave walls and floor for mineralogical identification by X-ray diffraction – calcite, gypsum, quartz, arsenopyrite and brushite are the minerals found. A few samples of gypsum were also analysed for sulphur isotopes ($d^{34}S$) – the obtained $d^{34}S_{V\text{-}CDT}$ values range from -3.10 to 4.47 ‰. These preliminary results indicate that the maze pattern of Grotta dei Pipistrelli cave follows a local fracture network, showing evidence of a polygenic speleogenesis that includes a hypogenic origin and subsequent epigenic overprinting, with the latter conditioning the preservation of the archaeological record in specific cave sectors.

The Holocene neotectonic diversion of the Cotovelo River

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This research aims to investigate the diversion of the Cotovelo River channel as a probable tectonically-controlled feature in an intraplate environment. The Cotovelo River catchment drains 788 km² of the Western São Francisco Craton foreland basin, in the Western Brazilian Atlantic Shield. Although it flows to the Southeast upper stream, the river is sharply diverted to the Southwest in the middle valley, in an almost right angle bend, a feature that nominated the river, *Cotovelo* (elbow in Portuguese). Thus, the elbow denotes the point where the Cotovelo River was deflected to Southwest. However, there is a 7 km-long wind gap, geometrically aligned to that upper channel, crossing the low and diffuse meridional watershed, where alluvial sands and pebbles pave extensively the landscape. Matching this wind gap direction, run a water gap, presently drained by the Pedras Creek, straightforward toward the South, to the Paracatu River. During the summer rainy season, the wind gap is filled up by rainwater, arranged in a straight N-S line of ephemeral lakes and flatter hydromorphic bodies. The water confinement in these lakes is due to topographic lows, conforming a dry channel, delimited for 5 to 10-m high levees. Three alluvial sediment samples collected in the watershed at 0.85 and 1.30 m-deep, and dated by OSL, yielded absolute ages between 3,300 (±350) ka and 13,065 (±1,295) ka, pointing to Upper Pleistocene to Holocene deposition. Other samples gathered in terraces inside the current floodplain, gave younger ages, between 1,100 (±175) ka and 3,880 (±180) ka. Therefore, diversion occurred entirely in the Holocene, resulting from very recent and astonishingly rapid tectonic lowering, processed westward, which become headward erosion operative, probably in small ravines or first order creeks. This subsiding block led to the capture and diversion of the Cotovelo River to Southwest, toward the Paracatu River, upstream the older mouth, with a very marked Northeast-Southwest oriented drainage, controlled by impressive dissected sedimentary walls; the current floodplain stands 30 m lower than the paleo-valley. Structural evidences of the subsidence are hidden under sandy, pebbles, and gravelly thick coverages, waiting to be disclosed. This diversion reinforce intraplate neotectonic reactivation hypothesis.

Coastal switching of dominant depositional process according to the decreasing rates of Holocene sea-level rise in the macrotidal coast of Gochang, SW Korea

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Decreasing rates of eustatic sea-level rise during the Holocene accompanied the deposition of transgressive coastal deposits worldwide. However, unraveling how transgressive deposition varies in response to different rates of relative sea-level (RSL) rise is limited by the scarcity of long (10+ m) well-dated cores spanning the entire middle to late Holocene record along macro-tidal coasts. To investigate the sedimentary response of this macro-tidal coast to decreasing rates of RSL rise, we acquired four cores up to 32 m in length and Chirp seismic profiles along the west coast of Korea. Core sediments were analyzed in terms of sedimentary texture, structure, and facies. Nineteen optically stimulated luminescence (OSL) and fourteen ^{14}C accelerated mass spectrometry (AMS) ages constrain the timing of deposition within the sandy sediments. This relatively dense distribution of ages was used to determine how depositional rates changed through time. We also used a compilation of previously published RSL indices for the southwestern Korean coast in order to better constrain RSL changes through time. Results show that the evolution of the Gochang coastline switched from a tide-dominated environment to a wave-dominated environment during the latter stage of transgression as the rate of the sea-level rise decreased. Rugged antecedent topography likely led to the development of tidal currents and the formation of a tide-dominated tidal flat during rapid RSL rise from 10 to 6 ka. As the tidal channels filled with fine-grained sediments from 6 to 1 ka, tidal-amplification likely waned leading to a greater role of wave energy in shaping the formation of the sandy open-coast tidal flat. Since 1 ka, wave-dominated environments formed sand-rich tidal beaches and flats. Decreasing changes in rates of the RSL rise resulted in changes in depositional environments from a tide-dominated intertidal flat to an open-coast tidal flat and finally a wave-dominated tidal beach. This study highlights the important role that rates of RSL rise play on not only sedimentation rates within a shelf setting but also playing a role in the switch from a tide to a wave-dominated setting.

Incised-valley filling sedimentation of the wave-dominated embayed coast in response to Holocene sea-level rise, Yeongil Bay in SE Korea

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The Yeongil Bay is on the southwestern part of the East Sea (Sea of Japan), and is a semi-enclosed, funnel-shaped morphological feature in the land direction on the east coast of Korean peninsula. The Hyeongsan River incised valley lies east of the bounding fault zone and runs seaward, approximately parallel to it. The incised valley deepens to more than 160 m below mean sea level near the coast, deeper than sea-level fall during the Last Glacial Maximum, because of subsidence governed by the fault zone. In this study, we examined the sediment stacking patterns of the incised-valley fill by analyzing sedimentary facies and OSL and radiocarbon ages from three sediment cores from the Pohang city. The latest Pleistocene to Holocene Hyeongsan River incised-valley fill sediments unconformably overlie a basement of semi-consolidated Tertiary deposits. The infilling sequence comprises sediments of fluvial lag and meander (>12 cal kyr BP), estuarine (12–8 cal kyr BP), and deltaic (8–0 cal kyr BP) systems, in ascending order. Thousand-year isochrons based on OSL and radiocarbon ages show that the fluvial and estuarine systems were deposited retrogradationally and the deltaic system was deposited progradationally stacking patterns. These sediment stacking patterns resemble those of other incised-valley fill sequences indicates that the last deglacial eustasy was a major factor controlling sediment stacking patterns of incised-valley fill sequence.

The Role of Sub-daily Weather Variability on Rock Cracking across Arid to Semi-arid California throughout the Quaternary

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Geomorphologists and soil scientists commonly leverage mean annual temperature and precipitation to construct climosequences of field data. Yet many surface processes are driven by extreme conditions associated with daily or even hourly weather. Thus, longer-term climate means cannot reflect the full range of conditions the rocks are subjected to at different sites. Here, as part of a broader study to interrogate how climate impacts rock weathering, we estimate the influence of short-term weather variability on longer-term mechanical weathering.

Acoustic emissions field data have shown that, outside of freeze-thaw environments, rock cracking occurs during periods of high stress associated with diurnal heating cycles (Eppes et al., 2016), and that cracking rates for any given stress are exponentially larger during periods of high atmospheric vapor pressure (Eppes et al., 2020). While the daily stress from solar cycles is relatively constant across decades, the field data suggest that instances of high vapor pressure on timescales of hours to days could disproportionately influence the overall cracking rates. Our preliminary analysis suggests that hourly environmental conditions may contribute to cracking rates as much as the variations in longer-term seasonal to decadal climate variability.

In this study, we utilize sub-hourly weather data from three Eastern California field sites and determine that hourly resolution captures the fluctuating weather conditions that influence cracking, and this variability is broadly underestimated when utilizing mean annual values. For example, >10 years of hourly data show that vapor pressure extremes in the arid site are 47% higher than the semi-arid site, while mean annual vapor pressure at the arid site is only 28% higher than the semi-arid site. Utilizing mean annual conditions to understand the influence of climate at these sites would significantly underestimate the difference in vapor pressure extremes.

Due to the importance of hourly-resolution data, we apply perfect prognosis modeling to estimate the magnitude of paleoclimate weather events over the last ~30 ka, leveraging paleoclimate predictions and overprinting modern weather trends. Our goal is to estimate the importance of high-resolution weather variability for paleoclimate analysis of mechanical weathering, and we welcome suggestions and criticisms.

Back-barrier evolution and along-strike variations in infilling of the Kosi Bay lake system, South Africa

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The Kosi Bay system comprises four interconnected lakes with varying degrees of marine influence. Their location behind a continuous coastal barrier predisposes them as excellent archives of environmental change related to changing sea levels and sediment supply. In this context, two cores were extracted from the system, together with over 150 km of seismic reflection profiling. A major unconformity surface (SB) was identified that incised the underlying unconsolidated sandy basement, in which multiple slumps filled the early valley form. The slumps are coeval with a Holocene-age muddy fill indicative of quiet water conditions in the back-barrier. These intercalate with thick prograding spits that comprise the dominant infill of the lakes. Two forms are evident, C1 progrades from the palaeo-highs of the valley interfluves into the nearest available accommodation space. Unit C2, progrades from the margins of the system into the basin. The two separated by an erosional surface formed by migrating tidal channels as sea levels rose and marine waters entered the system during the Holocene. These are in turn associated with younger slump deposits formed on the steepest part of the margins which post date ~3000 yr BP. Unit E caps the stratigraphy and is interpreted as lacustrine fines with a thin layer of acoustically transparent material (gyttja) at the top. This kind of stratigraphic arrangement is not yet reported from the global estuarine and incised valley literature. Future work entails an examination of the fines in the context of the changing hydroclimate of SE Africa.

Role of aeolian sedimentation and mass movements in the evolution of kettle-holes of glacial flood origin

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Sandur kettle-holes of flood origin are landforms formed after melting buried blocks of glacial ice. They undergo intensive transformations at the initial stage and become stabilised by the plants' colonisation. The main aim was to determine the quantity of aeolian sedimentation and assess the role of mass movement processes in transforming fresh landforms and those covered by vegetation. The fieldwork was carried out in the Skeiðarárjökull forefield (S Iceland) in VI.2021 – VI.2022. Material deposited in young kettle-holes – not colonized or poorly covered by vegetation (25 years) and in overgrown, older landforms (80–90 years) was obtained. The amount of deposition was, on average, 5 kg per m^2 in the younger depressions and was six times higher than in the corresponding older landforms and almost 15 times higher than on the vicinity of older kettle-holes. It was found that within the older depressions, the weight of the aeolian material is more than twice as high when it is deposited on mosses than on stones, grass, and heathers. These preliminary results show that kettle-holes are important sedimentation traps for wind-blown dust-sand material. The mechanism of retaining grains and incorporating them into the soil-forming process is closely dependent on vegetation and its ability to retain moisture. In the case of younger landforms, the dominant role is played mainly by mass movements and surface runoff. Up to 80–90 years after the depression is formed, approx. 70–85% of the mineral mass supply to the bottom comes from solifluction, debris flow and landslides. This share is much higher in fresh landforms and decreases with their progressive overgrowing. In the broader context of studies, Iceland's sandur areas will be used as an analogy for reconstructing palaeoenvironment sedimentation conditions for N Poland at the end of the Pleistocene.
Fieldwork was carried out thanks to funding from: the National Science Centre project "Development of a high-resolution digital elevation model (DEM) of kettle-holes of flood origin at Skeiðarársandur (S Iceland)", no. 2021/05/X/ST10/00710, the Director of the Institute of Earth Sciences of the University of Silesia in Katowice and Centre for Polar Studies in the University of Silesia in Katowice.

Tectonic Uplift, Subsidence and Erosion from Integrated Stratigraphy and Geomorphic Signatures in a Source-to-Sink System: the Case Study of Pagliara Basin, Northeastern Sicily, Italy

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How exogenic (e.g. tectonic) forces are encoded in coupled stratigraphic and geomorphic records in source-to-sink systems is still uncertain. Using sedimentological, geochronological, and geomorphic approaches, our work sheds light on the relationships between transient topography and delta environment deposition within an actively-deformed region. We present new luminescence ages and paleo-erosion rates for the late Pleistocene Pagliara fluvio-deltaic system and model the uplift and erosion of the source catchment located on the Ionian flank of the Peloritani Mountains of northeastern Sicily, Italy. The catchment feeding the deltas is characterized by steep channels incised into lower-relief interfluves with iso-elevation knickpoints, and shallow and bedrock-cored landsides on hillslopes. The Pagliara delta system is part of the broader Messina Sands and Gravel lithostratigraphic unit; these deposits outcrop along the coast due to recent basin inversion driven by the increase in uplift rate related to normal faulting along the Messina Straits. The deltas exposed at the mouth of the Pagliara River are ~100-200m thick, with constructional tops at ~300m a.s.l., and onlap steeply-dipping bedrock along the coast. Six infrared-stimulated luminescence (IRSL) ages collected from the delta range in age from ~180ka to ~125ka, indicating a vertical long-term sediment accumulation rate of ~1-2cm/yr over the latter half of the MIS 6 and MIS 5 glacio-eustatic cycle. Two cosmogenic 10Be concentrations measured in samples of delta sediment indicate paleo-erosion rates during the MIS 6-MIS 5 deglaciation similar to, or slightly higher than, modern rates of ~1mm/yr. Linear inversion of Pagliara fluvial topography indicates an unsteady uplift history that doubled in rate from ~0.9 to ~2.0mm/yr in the past 200ky. This increase in uplift rate at the footwall of normal faults implicate the further creation of accommodation space necessary to initially host the delta deposits in the basin, later uplifted and now exposed hundreds of meters above sea level. Given the location of the Pagliara delta system near the center of the footwall of a deforming normal fault embedded in an uplifting, translating, and fragmented forearc, our data contribute to define the role of major lineaments in the frame of the late Quaternary tectonic evolution of Central Mediterranean.

Event geochronology at the edge of the last glaciation

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We present the results of parallel and consecutive ^{14}C, OSL and ^{230}Th/U dating together with plant macrofossil and pollen analyses applied to the Upper Quaternary composite sedimentary succession located at the edge of the last Scandinavian ice sheet (SIS) southeastern flank. The sedimentary succession is comprised of a 65 km long series of the middle Severnaya Dvina River valley terrace sections named Tolokonka, previously studied in the early 2000s. Our studies conducted in 2012-2022 included lithostratigraphic and geomorphological survey, dating and palaeocological analyses that aimed to reconstruct the Upper Quaternary sedimentary setting in extra-glacial environment, the chronology of landforms' evolution and any abrupt/slow landscape changes.

The composite section contains a full record of the Late Pleistocene starting with Eemian (MIS 5e) organic-bearing oxbow lake sediments ^{230}Th/U dated to 120-104 ka BP which probably accumulated in the vicinity of the Boreal Sea. Palaeoecological record shows that climatic conditions changed from moderately cool and humid to warm and slightly dry and then again to moderately cool and humid. At the end of Early Weichselian and in the beginning of Middle Weichselian (MIS 5/4) alluvial beds of high-velocity stream (OSL-dated to 78-68 ka) with permafrost traces later during MIS 3 changed to the gentle floodplain and oxbow-lake sedimentation in the moderate climatic conditions, ^{14}C and ^{230}Th/U dated to 42-39 ka BP. A short warming at the beginning of MIS 2 ^{14}C-dated to 27.4-25.9 ka BP was followed by extreme cooling, and then the 100 km long proglacial lake was formed at the edge of the SIS glacial tongue. The hydrodynamic regime of this lake was unstable, and it was controlled by the glacial lobe oscillation and magnitude of glacioisostatic subsidence near the trimline. We reconstruct at least three episodes of proglacial lake drainage during the LGM (OSL-dated to 19-17 ka) in the extremely cold conditions and deep river incision in the Late Glacial (ca 16 ka). At the end of MIS 2 (16-11 ka), river terrace was formed and aeolian impact in the landscape formation became notable.

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Paleodischarge reconstruction of historical flood events in the Copiapó river (southern Atacama Desert, Chile). Implications for flood hazard assessment in arid basins

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The understanding of extreme event patterns in the context of global change is critical, particularly in arid fluvial basins where extremes are an inherent feature of their hydrological regime. However, long-term changes of rare events are difficult to identify due to short gauge records, of only a few decades in some cases. These need to be lengthened by reconstructing discharges of past floods using paleoflood evidence and/or historical descriptions. For this reason, we have studied an outcrop located in the Lower Copiapó basin (southern Atacama Desert, Chile) downstream the Angostura sector, where the valley narrows and incises the Palaeozoic bedrock forming a 10.5 km long canyon. In this sector, measured mean annual discharge is 0.43 m^3/s although extraordinary floods with peak discharges of 240 m^3/s have been recently recorded (March 2015 flood event). Downstream the Angostura canyon, where changes in the valley geometry result in a reduction of the flow velocity, 14 flood events have been identified in a terrace where slackwater deposits alternate with shale, peat and paleosoils, ranging from 541 BC at its base to the 19th century near the top. Quartz OSL dating of the 5 upper flood deposits has revealed a complex three-dimensional architecture of this bench as the highest flood unit gave an age of 377 ± 40 years and the other four below resulted in an average date of 146 ± 13 years. These dates were correlated with the historical flood record of the Copiapó river to identify the flood events that produced these deposits: AD 1655, AD 1877, AD 1882, AD 1888 and AD 1890. Finally, we used the software HECRAS to estimate the discharges associated with the slackwater deposits obtaining values ranging between 118 and 250 m^3/s. The 1655 event had a similar discharge to that of 2015 catastrophic flood. The flood frequency analysis of systematic and non-systematic data will increase our knowledge of future hydrologic and flood hazard scenarios in the southern Atacama Desert. Ultimately, we hope that this information will improve flood resilience in local communities in the context of present dramatic climate and hydrologic changes.

Changing flood dynamics on the large, flood-prone River Tweed (Scotland/England border) inferred from a luminescence-dated lake palaeoflood record

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River flooding is a costly and deadly hazard. Whether flood frequency and magnitude are changing due to climate change is a growing concern for communities, cities and countries. However, conventional time series of gauged river flow are usually a few decades in length or shorter, so capture only a snapshot of a river's flood regime and associated climate drivers. More comprehensive assessments require longer-term and often palaeo-hydrological data.

The River Tweed, one of the largest drainage basins in the UK, is notable for its biodiversity, fish stocks, drinking water provision and history of intense flooding. Historical records and alluvial sequences spanning the last 250 years have produced useful re-assessments of flood risk but lake sediment archives from the catchment are underused.

We report the first luminescence-dated lacustrine palaeoflood sequence, overcoming pervasive challenges with radiocarbon dating at temperate lakes dominated by eroded catchment soils. The sequence provides a 1000-year particle size record of flooding for the River Tweed. We apply a suite of complementary analytical techniques to high-resolution grain size measurements to disentangle event-scale flood signatures from the long-term variability in climate and anthropogenic landscape change. Integrating the event-scale sedimentary data with the historical flood record developed for the Tweed, one of the longest in the UK, confirms the reliability of our palaeoflood reconstruction.

We find the late-Holocene flood regime of the Tweed is dominated by multi-decadal clustering, with frequent flooding during the mid-1300s, late-1500s, 1650-1740, mid-1800s and since Common Era 1900. This dataset expands our understanding of spatially and temporally congruent flood-rich and flood-poor phases across the UK. We find some association between flood-rich phases and the negative winter NAO mode as well as the intensity of solar irradiance, in keeping with literature from elsewhere in the UK and northern Europe, but geochemical markers of land-use change also correlate with patterns in flood frequency over recent centuries. We apply a process-based approach to isolate climate and anthropogenic drivers, which produces insight into contemporary flood dynamics and facilitates the re-evaluation of flood risk for this nationally important river.

Outburst floods strongly influence valley evolution in the Tsangpo Gorge, Eastern Himalaya

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Regular flows and infrequent outburst floods shape many mountain landscapes, but the relative contributions from these gradual processes and infrequent high-magnitude events have been widely debated, in part due to a paucity of reliable data from historical outburst floods. Here we quantify erosion and deposition from a catastrophic outburst flood in June 2000, caused by a landslide-dam failure on the Yigong River in a rapidly exhumed region of the Eastern Himalaya. The flood, with a peak discharge of 10^5 m^3/s, lasted for only ~10 hours, but its geomorphic effects were equivalent to the cumulative effect of $1\text{-}2\times10^3$ years of long-term fluvial processes in the region. Ubiquitous boulder bars deposited in the channel by the flood promoted extensive lateral erosion through increased bed roughness. As a result, the valley floor widened threefold, triggering many additional secondary landslides, which contributed boulders to the riverbed. The resultant widespread bank erosion and concurrent landslides will continue to influence fluvial dynamics until the next catastrophic flood remobilizes the boulders. Our quantitative findings highlight the importance of recurrent outburst floods for gorge development and landscape evolution in southern Asia and in rapidly uplifting mountain belts worldwide.

Spatiotemporal pattern of flood episodes and climatic variability in southern New Zealand from 1862 to 2020

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In the Northern Hemisphere, more than 345 paleofloods studies have been published according to the PAGES Floods Working Group meta-database. In the humid temperate climate zones of the Southern Hemisphere, the number of studies is modest (approx. 21), thus the assessment of SH regional flood trends is a major goal in light of Global Change.

Our study focuses on the spatial-temporal reconstruction and climatic characterization of flood episodes in three southern regions of New Zealand from 1862 to 2020. We reconstructed three regional qualitative indices of flood severity and spatial incidence from documentary data provided by NIWA. The flood severity matrix integrates numbers of fatalities, witness description of peak flows, flooded area and geomorphological impact, losses of livestock, properties and infrastructure, evacuation and mitigation measures. Synoptic Sea Level Pressure maps were reconstructed from the 20CR Project to explore the influence of climatic variability

The three regional flood series (295 floods) show synchronous flood pulses around 1878, 1905, 1913, 1957, 1968, 1978, 1999 y 2008. However, other flood pulses are out of phase because of different physiographic settings, catchment size, location on the western or eastern slope of the Southern Alps, and exposure to oceans and paths of weather systems. In the West Coast Region seven of ten flood pulses recorded from 1862 to 2020 correlate with positive Southern Annular Mode, higher SST, blocking weather types in summer and lows over the Tasman Sea producing increased humid airflows from the north and northwest. In the larger Otago catchments, ten of fourteen pulses occurred during the positive phase of the Southern Oscillation Index with higher SST, blocking types in summer and autumn, and an increase in northeasterly winds. By contrast in Southland ten of fourteen pulses correlate with negative phases of the Southern Oscillation Index characterized by lower sea surface temperatures, more zonal flow, and troughs with stronger and more frequent winds from the west (summer) and the south (winter).

Finally, we will discuss the possible reasons (and limitations) why the trends of reconstructed flood indices show no increase during the last 158 years despite, the possible effect of Climate Change.

Modeling wetlands of tectonic origin in a representative upstream basin of the Pampas plain (Argentina) during present hydro-climatic extreme events: Geomorphologic thresholds controlling hydrodynamics.

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During the last few decades, the more frequent high-intensity storm events in the Pampa plain have generated a steady increase in the water table elevation near the surface limiting soil infiltration. The flat landscape alters the surface runoff and develops temporary water bodies (non-floodplain wetlands), enhancing the flood hazards in the upstream fluvial basins. This work aims at deepening the knowledge of the mechanisms that govern the response of small temporary wetlands of neotectonic origin. The study focuses on the Vila-Cululú sub-basin, a tributary of the Salado river (Paraná river basin) in the North Pampa plain. Structural depressions with rectangular patterns and a network of Pleistocene parallel ENE-trending palaeochannels characterize the area. These palaeochannels are deactivated by neotectonics and conditioned by a homogenous lithology (loess) and very gentle slopes. In some sectors of the study area, the palaeochannels intercept those depressions and significantly restrict the drainage network (low-order streams and artificial channels).
The research involved an integrated approach, including geomorphic and morphometric analyses based on remotely sensed satellite imagery in a GIS platform coupled with field and hydrometeorological data. A two-dimensional hydrological-hydraulic mathematical model of the Vila-Cululú system using the HydroBID Flood tool was set up to capture the system behavior for an extraordinary rainfall event (December 2016-March 2017). Model calibration was carried out using satellite images and the head-discharge curve in the outlet of the sub-basin. Spatial-temporal evolution of flow velocity and water depth maps obtained from the simulation at different time steps were evaluated in a geomorphological frame. Results show that some landforms act as control thresholds to surface runoff and isolate zones with a general dendritic flow pattern towards the neotectonic depressions. It leads to a more relevant surface water storage process. This flow pattern also highlights the poor capacity of both the natural and the artificial drainage network to conduct excess water to the sub-basin outlet. This work is one the first studies in the North Pampa that combine hydrological and Quaternary geomorphological data to explain hydrodynamics. Identifying critical thresholds adds to the knowledge of different levels of hydrology connectivity and risk of flooding.

Microbial community shift appears synchronous with the collapse of mammoth-steppe in subarctic Yukon during the Pleistocene-Holocene transition

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We analyzed the microbial constituents of previously published sedimentary ancient DNA (sedaDNA) sequence data recovered from subarctic permafrost sediments dating between 30,000–4,000 years ago. These samples were originally studied for macro-ecological shifts associated with the Pleistocene-Holocene transition. Our goal was to explore whether there were changes in microbial communities paralleling the transition from grazing megafauna (woolly mammoths, steppe-bison, and horses), forbs (herbaceous plants), and graminoids (grasses), which together formed the mammoth-steppe ecosystem, towards the expansion woody shrubs, extirpation of grazing megafauna, and development of the boreal forest. We observe a clear shift in the taxonomic composition of microbial taxa through this ecological transition irrespective of sampling site. We observe consistency in microbial communities between replicate core samples, including between two different extraction methods as well as shotgun sequencing and targeted capture. These data highlight that the ‘off-target’ fraction from studies using sedaDNA to study macro-ecosystems can also be used to more holistically investigate shifts in microbial communities that are coeval with major ecological transitions.

The taphonomy and taxonomic value of sedaDNA for animal community reconstruction

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As biodiversity is threathened globally, the reconstruction of past vegetation and animal communities is becoming an increasingly relevant tool in conservation efforts. Landscape history can provide benchmarks for landscape restoration and optimization. Vegetation can be reconstructed at a high taxonomic resolution through phytoliths and pollen, but the reconstruction of animal communities is still challenging and largely limited to coprophilous fungal spore analysis. This method is reliable, but provides a low taxonomic value of herbivores only. Sedimentary ancient DNA, however, is a new, experimental, paleoecological proxy with potential to uncover past animal communities at a high taxonomic resolution. Much is unknown about the taphonomic processes and taxonomic value that this method yields. As DNA degradation is accelerated by high temperatures, climate is often suggested to play a key role in whether or not sedaDNA can be extracted and interpreted from sediments. I compiled the research on taphonomic processes and the taxonomic value of sedaDNA over a range of climates, and found that water quality and lake morphology play a greater role than climate in the preservation of sedaDNA. The detection of sedaDNA of a particular species appears to be density dependent, making abundant or heard animals more easily identifiable than rare, solitary species. Careful consideration of both sampling site and sedaDNA methodology can optimize the taxonomic value of sedaDNA in past wildlife reconstructions. Therefore, I provide a framework for choosing the methodology and the sampling site based on the research question, the targeted species and desired spatial scale.

A needle in the haystack: Evaluating the potential of ancient DNA from conifer macrofossils preserved in lake sediments from the Swiss Alps.

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Over the last years, the analysis of ancient DNA (aDNA) has expanded in many fields, including palaeoecology. Thanks to the development of new sequencing techniques, palaeogenomic data allow observing demographic and evolutionary processes over time. While most of the studies still focus on animal remains and on material preserved in archaeological sites, only a few emphasize past plant communities. This scientific gap is relevant because studying genetic variation of plant populations through time and space is essential to understand ecological processes, such as postglacial range expansion or adaptation to climatic changes.

Lake sediments host ideal conditions for the preservation of plant remains for millennia and potentially for the conservation of endogenous aDNA therein. However, the preservation of biological remains also depends on different physical, chemical and biological processes, which may affect the DNA quality. Thus, it is not possible to predict the suitability of the samples for aDNA analysis based on appearance alone. Therefore, it is recommended to screen samples, e.g. using a PCR-based assay, to select the most promising material.

We analyzed the aDNA quality of subfossil plant material preserved in lake sediments of six localities over the Swiss Alps. These lakes are situated in key locations in the Eastern, Central and Southern Alps, along an East-West and a North-South transect. We are analyzing Lateglacial and Holocene subfossil conifer needles from *Larix decidua*, *Abies alba* and *Picea abies*, which are keystone species of the mountain forests in the Alps. We isolated the DNA in a dedicated aDNA facility and assessed the DNA quality by amplifying the chloroplast *trn*L P6 loop, a short universal plant barcode. The results of this study show different levels of DNA preservation in the lakes and will provide the basis to design a genome-scale aDNA analysis.

Our study has the potential to provide unprecedented data to track microevolutionary and demographic processes through time and identify possible adaptations to climatic and anthropogenic factors. Such data may refine regional assessments of post-glacial range expansions and recolonization routes of important conifer species in the Alps.

Pollen, macrofossils and sedaDNA reveal climate and land use impacts on Holocene mountain vegetation of the Italian Lepontine Alps

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Mountain ecosystems, and specifically the treeline ecotone, are very sensitive to changes in climate. However, climate change is not the only factor driving vegetation change over time; human land use also plays a major role. A better understanding of past vegetation dynamics is necessary to disentangle the influence of climate and land use and to assess future vegetation change. Here, we present the first multi-proxy palaeoecological study combining sedimentary ancient DNA (*sed*aDNA), pollen, spores, stomata, charcoal and plant macrofossils from the Alps. We reconstructed the Holocene vegetation dynamics and fire history at Lago Inferiore del Sangiatto (1980 m asl), a small lake in the subalpine belt of the Ossola region, Italian Lepontine Alps.

The sediment record of Lago Sangiatto starts during the Younger Dryas and spans the entire Holocene. Our results show that afforestation in response to climate warming started at 10,700 cal yr BP with *Larix decidua* and tree *Betula*, which formed open forests together with *Pinus cembra* from 10,500 cal yr BP onwards. Human impact on regional vegetation started at 5100 cal yr BP, resulting in expansions of *Picea abies* and *Alnus viridis* and the collapse of *Abies alba*. Species response models and ordination analysis show that livestock grazing and fire were major drivers of vegetation change at Lago Sangiatto during the late Holocene. Finally, increasing human impact during the Bronze Age and Iron Age led to the formation of species-rich larch meadows and alpine pastures that are still dominant today. The palaeoecological data suggest that under projected climate change and land abandonment, the treeline ecotone will likely shift to higher altitudes, leading to important changes in species composition and increasing the risk of biodiversity loss.

The strength of our study is the multi-proxy approach, combining classical palaeoecological methods with *sed*aDNA analysis. A major advantage of *sed*aDNA is the high taxonomic resolution for herbaceous plants, whereas pollen and macrofossils can quantitatively reconstruct biomass and vegetation dynamics. Our study shows how this combination can provide novel insights into the reconstruction of past ecosystems and their response to palaeoenvironmental change.

Linking Holocene and extant Mediterranean lowland Abies alba populations using population genetics and ancient DNA

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As a keystone conifer of European mountain forests, silver fir (*Abies alba*) has been the focus of many ecological, physiological, paleoecological, and genetic studies. Based on its extant distribution, *A.alba* is commonly assumed to prefer cool (<18°C July means) and moist habitats with abundant summer precipitation. However, paleoecological studies document high abundance of *A.alba* under Mediterranean climates (July means ca. 25-26°C) with moderate to severe summer drought, such as in coastal Tuscany (Italy). The widespread occurrence of *A.alba* populations during the last interglacial (Eemian) under higher temperatures further indicates a much wider climatic niche than anticipated. Besides, dynamic process-based modeling shows discrepancies between the realized and potential spatial range of *A.alba* during the late Holocene until today, corroborating paleoecological evidence that *A.alba* became regionally extinct due to anthropogenic disturbance (logging, browsing, slash-and-burning) at its warmest edge of the niche. Furthermore, some cryptic stands within the submediterranean and mesomediterranean lowland vegetation support the palaeoecological notion that *A.alba* can thrive under warmer and drier conditions.

Here, we perform population genetic analyses combining extant populations, including cryptic *A.alba* stands under warmer and drier climates, and ancient populations using ancient DNA (aDNA) analyses. We will genotype several *A.alba* populations across Switzerland and Italy with selected neutral single-nucleotide polymorphisms (SNPs) to link them to well-known (cool-temperate) populations in central Europe via Bayesian population structure analysis. This will allow us to check whether these cryptic stands are specific or of local origin and might thus be direct descendants from warm-adapted Holocene *A.alba* populations, or if they are deriving from other origins. Central-marginal hypothesis and isolation by distance scenarios will be tested, considering several proposed primary Last Glacial Maximum and secondary Late-Glacial refugia, as well as Holocene expansion of *A.alba*. Additionally, we will link extant populations to Holocene extinct populations known to have grown under warm conditions (approximately 23-24°C July means) via hybridization capture of these SNPs in aDNA from needles preserved in the lake sediment of Lago d'Origlio (Ticino). Our results will allow a detailed understanding of the current population structure, reconstructing their history, and help identifying populations that may be adapted to future climate conditions.

Palynology and sedaDNA metabarcoding as complementary tools to reconstruct vegetation history at Lago di Mezzano in central Italy

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Understanding the linkage between past vegetation dynamics, climate, and human impact can be critical to coping with ongoing climate change. The reconstruction of past vegetation history by means of palynological studies has been carried out at many sites in Europe and elsewhere. However, the determination of plant species through pollen identification shows some limitations, for instance pollen determination may sometimes reach only the plant genus or family level. Moreover, the pollen of some important insect-pollinated species might not be well dispersed or in extreme cases, when the exine is missing or thin, not preserved.

Metabarcoding of lake sediments ancient DNA (*sed*aDNA) has proven to be a powerful tool for the identification of rare plant species. The combination of palynological data with *sed*aDNA provides the opportunity to discover more details on the composition and diversity of specific plant communities. However, in the Mediterranean region this palaeoecological approach is still poorly implemented, and more studies are needed.

Here, we present the first results of our study on the sediments of Lago Mezzano (a maar lake located at 452 m a.s.l. in central Italy), which combines pollen, spores, charcoal and *sed*aDNA analyses. High-resolution Neolithic vegetation history is reconstructed using pollen and *sed*aDNA from the same sediment depths to investigate complementarity. Preliminary results on 26 tandem samples show 107 plant taxa (43 arboreal and 64 herbaceous) based on palynology vs. 75 (28 arboreal and 47 herbaceous) based on *sed*aDNA. The detection of dissimilar taxa and vegetation dynamics in palynology and *sed*aDNA suggests complementarity in both, taxonomic resolution and spatial origin between the two palaeoecological proxies (e.g. extralocal vs. local). Moreover, although the two records only partially share statistically significant changing vegetation zones, they show similarities in richness variation, which in both cases increases slightly over time. This study is intended to provide novel insights on the composition of specific plant communities, and their relationship with human activities, fire, and climate. Given that assessments of future community changes require a thorough understanding of long-term vegetation dynamics, our data may contribute to improve projections of ecosystem responses to global change conditions.

Sedimentary ancient DNA reveals local vegetation changes driven by glacial activity and climate

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Disentangling the effects of glaciers and climate on vegetation is complicated by the confounding role that climate plays in both systems. We reconstructed changes in vegetation occurring over the Holocene at Jøkelvatnet, a lake located directly downstream from the Langfjordjøkel glacier in northern Norway. We used a sedimentary ancient DNA (*seda*DNA) metabarcoding dataset of 38 samples from a lake sediment core spanning 10,400 years using primers targeting the trnL P6 loop region. A total of 193 plant taxa were identified revealing a pattern of continually increasing richness over the time period. Vegetation surveys conducted around Jøkelvatnet show a high concordance with the taxa identified through *seda*DNA metabarcoding. We identified four distinct vegetation assemblage zones with transition periods at ca. 9.7 and 4.3 ka mirroring climatic shifts recorded by the Langfjordjøkel glacier. Soil disturbance trait values of the vegetation increased with glacial activity, suggesting that the glacier had a direct impact on plants growing in the catchment. Both temperature optimum and moisture trait values correlated with glacial activity and reconstructed climatic variables showing direct/indirect effects of climate change on the vegetation. In contrast to other catchments without an active glacier, the vegetation at Jøkelvatnet has displayed an increased sensitivity to climate change throughout the Middle and Late Holocene. Beyond the direct impact of climate change on arctic vegetation, our results suggest the ongoing disappearance of glaciers will have an additional effect on plant communities.

Extraction of modern and ancient RNA from single pollen grains

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Pollen deposited in natural archives such as lake sediment is a well-established proxy in paleoecology to study vegetation responses to past environmental changes. However, only a handful of studies have tried to use the full potential of this proxy by additionally analyzing genetic information preserved in subfossil pollen grains. Until now, these studies have been limited to traditional PCR-based Sanger sequencing techniques focusing on specific marker regions on the chloroplast or mitochondrial genome. Due to large expenditures in single pollen preparation and handling as well as low PCR recovery rates, this approach has not been developed further. Particularly since recovering the same information directly from the sediment matrix has proven to be more efficient and effective, leading to the establishment of the field of sedimentary ancient DNA (*sed*aDNA) analysis. Here, we applied novel single cell sequencing techniques to pollen grains from a variety of environments and time periods. Specifically, we tested if we can reliably recover modern and ancient transcriptomes from a large number of pollen grains using the Chromium Single Cell Gene Expression application from 10x Genomics. The analysed pollen come from fresh (modern) plant material, herbarium collection (museomics) and lake sediment archives. This novel approach has the potential to significantly improve the taxonomic resolution of pollen analysis and track postglacial range shifts in response to past climatic changes in unprecedented detail. If successful, this pilot study will pave the way for larger research projects that have the potential to revolutionize the fields of paleoecology and population genetics, by opening a window into the past and provide a glimpse of the future.

Ancient sediment DNA shows biodiversity change in the Anthropocene

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Human impact on the Earth System exponentially grew during the last centuries, with marked increase during the Great Acceleration of the Anthropocene in the 20th century. Biodiversity rapidly changes as a result, with climate change, pollution, overexploitation, species invasions being recognised as major drivers. These drivers are largely collinear during the Great Acceleration and existing biomonitoring data is not sufficiently long-term to separate their effects. Here I combine sedimentary DNA-based lake biodiversity data with proxies (heavy metals, organohalogen pesticide and nutrient pollution) and global records and models of human impact (temperature, CO2, nitrogen enrichment), and parametrise a structural equation model to disentangle drivers of biodiversity change during the last two centuries. The results suggest that different aspects of lake biodiversity are driven by different drivers: CO2 and phosphorus enrichment is linked to a departure of community composition compared to baseline conditions, temperature is linked to increased species richness, CO2 is linked to general biomass increase. Surprisingly, the models found no direct effects of heavy metal and pesticide pollution on any investigated aspects of lake biodiversity, but suggest a large and unexpected early effect of CO2 on freshwater lake ecosystems. The study is a blueprint of how sedaDNA time series can be integrated with proxies, records and models of human impact into a theoretical community ecology framework, and how this may differentiate collinear drivers of Anthropocene biodiversity change.

Optimizing DNA isolation from small ancient plant remains

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Ancient DNA (aDNA) provides a unique opportunity to track genetic variation over time and observe demographic and evolutionary processes. Driven by recent advances in DNA isolation, library preparation, and next-generation sequencing, ancient whole-genome sequence data are becoming available at a rapid pace. Because DNA preserved in ancient biological material is present in only minute amounts and degraded to short fragments, DNA isolation remains a critical step in paleogenomic studies. The methods most widely used to purify and concentrate DNA from ancient material are based on absorption of the DNA to silica particles by supplementing the extraction buffer, used to release the DNA from the sample powder, with a buffer containing chaotropic salt. Refinement of this method for ancient bones and teeth allowed efficient recovery of DNA fragments as short as 25 bp. Currently, different protocols for aDNA isolation from a variety of tissues exist, but they have not been stringently compared for their efficiency in recovering ultrashort aDNA fragments.
In an attempt to optimize DNA isolation from small ancient plant remains, we applied a two-step approach. First, we compared four silica-based DNA purification methods by digesting plasmid DNA with a restriction enzyme to obtain equimolar amounts of short DNA fragments (9 to 622 bp). We show that all four purification methods allow for recovery of DNA fragments as short as 15 bp but that the addition of a widely used plant aDNA extraction buffer shifted the size distribution to DNA fragments of > 67 bp in one of the methods. Because the size distribution of the sequences is also influenced by the library preparation method, we prepared single stranded libraries using a method developed for degraded DNA and assessed incorporation of the restriction fragments by sequencing. In step 2, we used the two best-performing DNA purification methods to isolate DNA from individual 12,700–5,000 years old *Larix decidua* needles and prepared libraries. Finally, we evaluated the performance of the two purification methods based on fragment size distribution of chloroplast DNA. Our optimized protocol will greatly facilitate the extraction of aDNA from ancient plant remains and open macrofossils to the paleogenomic era.

Paleo-ecological changes in Danube river palaeo-channels and diadromous fish taxa

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Preliminary results from eDNA analyses of sedimentary archives taken from pale-channels of Danube river (Serbia) complemented with aDNA from sturgeon archaeological specimens. The sampling was performed at three different site locations selected for their vicinity to archaeological sites: Starčevo, Donja Branjevina and Magareći Mlin (Vojvodina Region). We performed metagenomics analysis of the old fluvial system to track human-environment interactions from the Early Neolithic to Middle Ages and in particular with the purpose of detecting the presence of extinct fish species in the sedimentary record. We integrated our study with population genetics analysis on archaeological specimens from sites along the river. This poster aims at presenting preliminary results and the potential of paleo-channels for future studies of past ecosystems.

Long-term ecosystem impacts of distal ashfall from a large volcanic eruption in eastern Beringia.

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Natural disasters can have profound long and short-term ecological impacts, both locally and regionally. Volcanic eruptions can deposit tephra across the landscape hundreds to thousands of kms from the source volcano, burying entire landscapes with devastating impacts on plants and animals. The ecological effects of these ashfall events have been studied in the context of modern eruptions but are only known sparsely from the geological record. About 30,000 years ago, a massive volcanic eruption in the Aleutian archipelago deposited tephra across eastern Beringia, resulting in deposition of the Dawson tephra with thicknesses ranging from 10 to 80 cm more than 1500 km from its source. This tephra is in loess deposits in Yukon and Alaska, including perennially frozen silt deposits in the Klondike area. These frozen silt deposits are ideal conditions for recovering ancient environmental DNA preserved in sediment (*sedaDNA*). We will use taxonomically sensitive *seda*DNA data to characterize the long-term impact of the Dawson tephra using multiple exposures from the Klondike area. Using a bait-based hybridization capture approach, we reconstruct ecosystems before and after the eruption and subsequent ashfall to observe how plant and animal communities responded to the disturbance. The results of this study can be used to understand the resilience of Arctic communities in response to ecological disturbances.

Residual soil sequence (MIS 5 – MIS1) on a thin loess mantle at the Upper Palaeolithic site Dzbańce 21 (northern edge of the Moravian Gate, SW Poland)

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Thin loess covers (<2 m) are commonly found in southern Poland at the transition from thick loess to clastic sediments with a slight contribution of aeolian dust. Many papers show that the formation of this thin loess mantles was a short-lived event that occurred during and just after the Last Glacial Maximum (LGM). Investigations of the archaeological site Dzbańce 21 located on the plateau of the Głubczyce Upland showed the possibility of a different scenario of the formation of thin aeolian silt cover and its pedogenic alteration. The sediment sequence documented in the trenches overlies Pleistocene deposits with fluvioglacial characteristics and/or pre-Quaternary age. The sequence has a generalised structure Ap-Bt and represents sediment which involved a long-term and multi-stage pedogenic transformation. There are no pedogenically unaltered loess layers. The key features of soil profiles are the multiplicity of Bt horizons (up to 5 subhorizons) and the truncation. The different Bt subhorizons are clearly distinguishable from each other in lithology, morphology and colour; the boundaries between them are clearly erosional in nature. The results of OSL dating confirm the complex genesis of the soil horizons. The youngest date (21.1±1.4 ka) sampled from the Bt2 indicates the Upper Pleistocene (MIS 2) age of the loess material. This is also an archaeological layer (Gravettian or Epigravettian complex) in which flint artefacts, charcoal fragments and bone remains were found *in situ*, approximately 30 cm above the youngest dated sample, suggesting an age of the site younger than the cited date. Bt3 horizon has an OSL age of 60-57.3 ka, which correlates with the older part of MIS 3; this is a reduced interstadial soil. The lowermost horizons (Bt4-Bt5) with an OSL age of 161-183 ka represents a bipartite horizon of mature soil (Eemian Interglacial) developed on loess of the penultimate glaciation. The investigated site is the proof that we need to take a wider view at the specific environment for the formation and preservation of Late Pleistocene soils in a high topographic location exposed to a strong influence of periglacial erosion processes, with a probable lack of supply of fresh aeolian material.

Palaeoenvironmental significance of the sandy-palaeosol sequences in the central part of the European Sand Belt

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Knowledge of the distribution, types and properties of fossil soils is essential in understanding landscapes and their variability occurring over time. It's also an indispensable requirement for assessing short- and long-term human impact, considering soil erosion and land cover change dynamics. In the central part of the European Sand Belt (Central Poland) 21 key sites with palaeosol-aeolian successions have been documented and analysed. The study employed a multidisciplinary approach using geochemical, spectrophotometric analysis and radiometric dating measurements. Considering the study, most of the documented fossil soils have a simple A-C or at most A-B-C structure. The best developed are Podzols. The results of 14C dating of the charcoals preserved in the structure of the palaeosols, while controlling for the OSL age of the sandy sediments, indicate that the soils described were formed during the warm periods of the Late Glacial and can be correlated with the "warm" units recorded on the Greenlandic climate change curve. Therefore, they are therefore initial, simple interphase soils or at most of interstadial rank. A surprising fact is quite commonly recorded in sandy-palaeosol sequences is the presence of well-preserved charcoals forming continuous layers and resembling well-developed A soil horizons. Observations of the morphology of the soil profiles, extended by the results of paleobotanical analyses, allow us to associate these layers with the vegetation of zones of more fertile habitats and overgrown by woody vegetation located on the periphery of the dune fields. So, their presence indicates the local redeposition of burned plant remains into the periphery of currently formed dunes. In turn, the layers with charcoals allow us to consider these sequences as unique archives recording environmental changes occurring in the surroundings of the analysed dune fields. The origin of the charcoals layers needs to be clarified - are they evidence of natural or human-induced fires?

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Sediment-paleosol successions in the Mongolian forest-steppe as archives of Late-Pleistocene to Holocene geomorphological processes, including hints for the onset of human impact

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The central-Asian forest-steppe forms the transition between the Gobi Desert in the south and the Siberian taiga in the north. In this sensitive landscape, even slight climatic shifts and minor human influence may lead to changes in vegetation patterns and geomorphological processes. Numerous alluvial and colluvial geoarchives, including successions of paleosols and periglacial, eolian, alluvial and colluvial sediments, indicate that diverse geomorphological processes have been active with varying intensity in different periods over the Holocene, shaping this landscape. Characteristic dark sediment layers, including soil material, charcoal and plant remains, are often embedded within the sediment-paleosol successions. They suggest that very often fires were the triggers that disturbed the vegetation cover and induced soil erosion.

Against this background, the aim of our work was to identify periods of enhanced geomorphological dynamics and relative stability with dominating soil formation, and to identify potential links with fire frequency. We focused on the forest-steppe in the northern Khangai Mountains, central Mongolia. Our approach included field observation and sedimentological analyses in combination with OSL and ^{14}C dating.

During the period between 9.5 and 4.5 ka before present, the region was largely covered by Siberian larch forests. Minor charcoal occurrence in the sediments of this time points to negligible fire activity. This phase of relative geomorphological stability is documented by a well-developed paleosol in several sediment-paleosol records. Geomorphological processes substantially intensified around 4.5 ka, as indicated by rapid accumulation of colluvial, eolian and alluvial sediments, including dark layers that are rich in charcoal and soil organic matter. Although the climate became more humid, forest fires became more frequent than during the previous warmer and drier periods. With the development of pastoralism since the early Bronze Age and associated population growth, the grazing pressure in the region increased. Its expression in the sedimentological records is very similar to that of aridification.

Late Quaternary aridification in central Iran: Signals from high-resolution distribution of stable isotopes in a palaeosol

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Aridification during the late Quaternary is recorded in subtropical deserts around the world but the onset of this process varies in different regions. Here, we report the first data on timing and trend of aridification in an arid region of central Iran based on stable carbon and oxygen isotopic composition of pedogenic carbonates. A relict, gravely and non-calcareous palaeosol in alluvium materials of a stable landform in eastern Isfahan was selected to study. High-resolution sampling strategy (10cm intervals) was used for soil samples and stable carbon and oxygen values were measured using mass spectrometry. Radiocarbon chronology of calcite coatings on the gravels showed that calcite deposition began around 32ka B.P. and deep carbonates were formed between 32-26ka B.P. It seems that aridity in the region started around 26ka B.P. and intensified gradually during the Last glacial maximum (LGM) and the Holocene as reflected in both leaching depth and the distribution of oxygen isotopic composition of matrix carbonates. Stable carbon isotopes of matrix carbonates revealed an increase in $\delta^{13}C$ values around 20ka B.P. which is likely related to a decrease in vegetation cover and influx of atmospheric CO_2 in response to cool and arid conditions during the LGM. Significant enrichment of both $\delta^{18}O$ and $\delta^{13}C$ values of matrix carbonates in the late Holocene (~4ka B.P.) proves the establishment of arid conditions with minimal leaching conditions, high rates of atmospheric CO_2 and calcareous dust influx with extreme evaporation rates in the region. This study highlights the efficiency of high-resolution analysis of soil matrix carbonates in paleoenvironmental reconstructions.

Influence of Long-term straw returning and manure application on soil erosion resistance

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Organic materials addition is considered an effective practice to prevent soil erosion by changing the soil physiochemical properties. However, the potential effects of long-term application of organic materials to soil on rill erosion is unclear. In this study, the effect of organic amendments on soil erosion resistance in non-calcareous fluvo-aquic soil under five fertilization treatment were interpreted. The treatments included: (1) CK (no fertilizer), (2) □ (wheat straw +276 kg N ha^{-1}), (3) □ (wheat + maize straw), (4) □ (wheat + maize straw+276 kg N ha^{-1}), (5) □ (pig manure 60000 kg ha^{-1}). The results showed that compared to CK, □ and □ significantly increased the soil critical shear stress by 83% and 40%, and reduced rill erodibility by 25% and 57 %, respectively. The optimal partial least squares regression model showed that <0.053 mm soil aggregates were positively correlated with soil critical shear stress because of the large surface area of silt and clay, which can lead to a strong chemical binding and adsorption capacity and subsequently a high soil stabilization. The optical density ratio at wavelength of 465nm and 665nm (E4/E6 ratio) of humic acid had a negative effect on rill erodibility maybe due to the increase of alkyl carbon, a hydrophobic matter preventing the soil aggregates from water disperse. The <0.053 mm soil aggregates in the □ treatment was 45% lower than that in CK. Compared to CK, treatments of □, □, □, and □ significantly increased the E4/E6 ratio of humic acid by 11%, 6%, 19%, and 39%, respectively. The results indicated that the application of pig manure alone and combination of wheat straw and nitrogen fertilizer could improve the soil physicochemical properties, which was beneficial to the improvement of rill erosion resistance.

Modelling the effect of climate, dust deposition and climatic precession on paleosol development on the Chinese Loess Plateau

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The loess-paleosols sequences in the Chinese Loess Plateau (CLP) are the most comprehensive terrestrial palaeoenvironmental records for paleoclimates, reflecting global scale climatic oscillations, glacial-interglacial phases. Environmental conditions over the Quaternary period have resulted in continuous loess deposits during glacials (cold-dry), which nevertheless interrupted by paleosols during interglacials (warm-humid) in the CLP. However, paleosols in there are least well understood in response to relative contributions of various soil forming factors, including climate conditions during interglacials (e.g. precipitation, evapotranspiration), duration of soil formation, dust deposition etc. One of the objective of this research is to better understand paleosol formation in the CLP, particularly through quantitatively assessing paleosol responses to interglacial climates. As far as climate is concerned, astronomical forcing play an important role in regulating glacial-interglacial cycles during the Quaternary period and have been found to be indirectly linked with paleosol development in the CLP. However, how astronomically-induced climate change has affected paleosol development is still unclear through changes in climatic variables. We use SoilGen2-LOVECLIM process-based soil-climate models to simulate paleosol development using time series of climate data (e.g. precipitation, temperature, dust input). Our results show that the simulated soil properties (mass of calcite and clay) are sensitive to precipitation, dust addition and potential evapotranspiration in a different order of sensitivity. Interestingly, results shows an indirect link between the simulated soil properties (calcite and clay content) and precession through its control on precipitation in the last five interglacials.

Superposed karstic and fluvial drainage networks in the Zadorra River Catchment (Northern Iberian Peninsula)

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The Zadorra River is one of the main tributaries of the upper catchment of the Ebro River, which represents the main river of the Northern Iberian Peninsula flowing to the Mediterranean Sea. The middle zone of the drainage basin, carved on a thick Upper Cretaceous calcareous sedimentary sequence of the Ganboa Mountains (Northern Álava province), displays interesting elements and landforms indicating fluviokarstic origin. The dissected materials comprise a WNW-ESE trending alternance of marls, marly limestones and locally thick limestone-calcarenite beds of Coniacian to Santonian age affected by to large fracture systems of NE-SW and NW-SE orientation controlling the drainage pattern.

The geomorphological analysis of the area identifies two contrasted types of fluvial incision (a) purely fluvial, and (b) fluviokarstic. In this last type, the drainage network follows mainly the bedding direction displaying a typical subsequent parallel pattern, but locally transverse streams following the NE-SW fracture-system generate small-scale gorging consequent to the bedding suggesting a case of drainage superposition. Noteworthy, these valleys appear exclusively constricted to the location of the interbedded thick limestone-calcarenite lenses. Contrary to the v-shaped fluvial valleys, the fluviokarstic valleys are relatively short (< 1 km length), with wide and flat bottoms directly carved on the bedrock (no infilling deposits) of u-shaped morphology. Purely fluvial valleys are controlled by the bedding of the Cretaceous bedrock with a minor fracture control in their pattern. Considering the overall landform assemblage in the studied area, fluvial valleys seems to be in an apparent younger stage of development than the fluviokarstic ones. Initially, karstic processes were constricted to the limestone-calcarenite beds, but dissolution processes propagated along the two main fracture-systems affecting the area (NE-SW and NW-SE), generating a primary fluviokarstic network in embryonic stage connecting surface and subsurface drainage. Further base-level driven fluvial incision connected subsequent drainage parallel to the bedding with the slightly oblique transverse fluviokarstic valleys. We suggest that the transition from the karstic modelling to the more recent fluvial modelling was in response to a change towards a more temperate-cold climate, maybe linked to the end of the Mid-Pleistocene Transition, around 700 ka ago.

New ice margin chronology for the North American Ice Sheet Complex based on a comprehensive database of chronological data: NADI-1

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The last North American Ice Sheet Complex (comprising the Innuitian, Cordilleran and Laurentide ice sheets) was in its extent and volume comparable to the present-day glaciation of Antarctica. Its ice margin chronology is important for a variety of research fields, from numerical ice sheet modelling to archaeology. Several previous generations of ice margin chronology relied exclusively on a database of radiocarbon ages. Here we present a new ice margin chronology from an updated set of radiocarbon ages (n=4916), cosmogenic exposure ages (n=2165 ^{10}Be and n=459 ^{26}Al), and optically stimulated luminescence ages (n=354). These data were screened for their quality and applicability in line with procedures introduced in recent reconstructions for other Pleistocene ice sheets. The newly-built isochrones capture the uncertainty in the ice margin position, with a minimum, maximum, and best-estimate ice margin position for each time step. We reconstruct a diachronous Last Glacial Maximum for the ice sheet complex occurring between 27 ka and 17 ka. In terms of the ice extent, the maximum occurred at 22 ka. The complete NADI-1 deglaciation chronology will be available in multiple formats and will include the underlying chronological data and extensive justification texts explaining the choices taken when constructing each of the isochrones.

Innovation at the beginning of the last glacial cycle in the neandertal populations of southwestern Europe. Quina strategies from level D of Axlor cave (noratlantic Iberia)

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The installation of cold environmental conditions in Europe at the beginning of the last glacial cycle (circa 70 ka) encouraged innovations in the technical and economic organization of the Neanderthal populations of southwestern Europe.

The origin and development of these innovations are documented at the Axlor site (noratlantic Iberia) where the Middle Paleolithic sequence extends over the period circa 100 to 50 ka. Level D, dated between the end of OIS 5a and the beginning of OIS 4, contains very characteristic Quina-type occupations. These occupations show changes in the mobility patterns and in the territorial ranges covered, with wider radii and very marked seasonal cycles. These strategies are based on the frequent exploitation of migratory ungulates and the use of raw materials for lithic tools collected over long distances. The technical innovations are oriented towards the emerging systems of production and management of stone tools that define the Quina type industries. Central to these strategies are standardized tools designed to be employed in particularly long cycles of use and resharpening. The massive use of bone tools for the processing of stone tools and some animal materials is also part of this strategy.

The occupations of Axlor level D constitute some of the oldest evidence of these Quinean innovations and therefore help to understand the genesis and structuring of these original strategies.

Soil formation on loess along a climatic gradient in Tajikistan

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Loess deposits are the major parent materials in Tajikistan and modern soil development studies and understanding the formation processes especially in different climate regions could provide an insight to the paleosols which are important archives of environmental changes of Late Pleistocene in Central Asia.

Ten soil profiles were investigated in a climate gradient with the mean annual precipitation and temperature range of 200-900 mm and 10-20 °C, respectively. The studied soils formed in the order of increasing precipitation were classified as Entisols, Aridisols, Inceptisols, Mollisols and Alfisols based on the American Soil Taxonomy and Regosols, Cambisols, Calcisols, Kastanozems and Luvisols based on the World Reference Base for Soil Classification (WRB). The dominant soil forming processes in the more arid regions of Tajikistan were calcium carbonate accumulation and redistribution, gypsum dissolution and salinization and alkalization. In the steppe regions organic matter accumulation on the surface horizons were the dominant process. With increasing water availability in more humid regions, carbonate dissolution and precipitation in the deeper horizons and subsequent clay dispersion and illuviation were dominant.

Thin sections were prepared from each horizon and studied using polarizing microscope. The parent material loess has a massive microstructure with very little marks of biologic activity. The microstructure in the soils varied from massive and weakly separated subangular blocky in the arid regions to moderately to well separated blocky in the steppe and more humid regions. The b-fabric is calcitic crystallitic in the regions with lower precipitation and changes to speckled in the soils with higher moisture availability. This provides conditions for the formation of depletion pedofeatures of calcite and clay coatings in the moister areas. The features related to the biologic activity such as excrements, needle shaped calcite and cytomorphic calcite are also dominant in the soils with higher organic carbon in the steppe regions. Pedogenic features in the studied modern soils well correlate with the present climate and could be applied for the interpretations of the existing paleosols in the region. This study was supported by of INSF (Iran National Science Foundation Project № 99006758) and NordForsk (THOCA project № 96926).

Soil piping – the key driver of landscape transformation in Yucatan, Mexico during the Late Holocene: implications for the Classic Maya collapse.

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Interaction of the Maya civilization with its environment and in particular the possible ecological reasons for the cultural collapse at the end of the Classic period have drawn major interest during the last years. The hypothesis of climate change impact ("the Mayan drought") was supported by various lacustrine, marine and speleological records; on the other hand, simultaneously the scenario of human-induced landscape degradation as an important factor of cultural decay was developed. In particular, soil erosion and loss of the soil mantle were considered to be the main mechanism of this degradation. Our research pretends to answer the following fundamental question: how could large-scale soil erosion develop in the Maya Lowlands – the Platform of Yucatan? This territory has even low-contrast relief with few pronounced slopes and besides lateral surface water flow does not develop because of vertical drainage through karstic cavities. Our research during 20 years demonstrated that vertical karstic erosion ("soil piping") could be responsible for the degradation of soil mantle. This process consists in the transport of soil material from the surface through the karstic sinkholes to the underground reservoirs: pockets, galleries and caves. Study of the underground pedosediments confirmed this process and revealed the soil materials deriver from surface profiles. Radiocarbon datings of charcoal, humus and terrestrial mollusk shells from these pedosediments produced ages corresponding to Formative and Classic periods (4000 – 1000 yr BP). In the light of these findings the origin of shallow soils – Rendzinas widely spread in Yucatan is revised. They could be not incipient young soils (as thought traditionally) but rather the relicts – minor residues of the pre-existing much more developed but then eroded profiles. Mineralogical and micromorphological results which show high weathering status of Rendzina groundmass agree with this conclusion. Ancient Maya cultivation was adapted to thin and discontinuous soil cover. However, the lack of soil thickness could have dramatic consequences for agriculture during the droughts because of decreased water storage in the soil.

Behavioral stability and ecological diversity in west African Middle Stone Age : a case study from Bargny, Senegal

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The Middle Stone Age is a crucial period in human evolution, during which numerous forms of ecological, socio-cognitive and techno-cultural adaptations are apparent. Discussions of these key issues typically exclude West Africa as archaeological data from this cultural stage has been scarce and archaeological sites characterized by poor chronological control. This paper presents the results of new investigations at Bargny, a quarry located approximately 2 km from the Atlantic coast of Senegal. Preliminary results make it possible to place human occupation in the Middle Pleistocene within a habitat associated withlow-levels of water stress and proximity to a mangrove environmental system. From a technological point of view, the classical elements of the MSA persisting in the region until the Holocene are represented. Notwithstanding the proximity to the ocean, no form of exploitation of marine resources has been revealed. This situation raises question about the diversity of trajectories in terms of environmental engagement and the relevance of the factors identified so far as drivers of cultural evolution.

Poster - sessions 21, 31, 59, 83, 101

Northward expansion of the westerlies and an extended LGM over southeastern Australia

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It has long been hypothesized that the last glacial maximum (LGM) oversaw cold, arid, windy climates across southern Australia, and that these were driven by intensification and northward expansion of mid-latitude westerly circulation. Additionally, it has been suggested (by Lynda Petherick, among others) that Australia experienced an extended LGM which began several millennia before the global peak. Aeolian sedimentary deposits provide key evidence for these hypotheses, and climate modelling an alternative means to test them. As yet, however, few studies combine modelling and sedimentology in order to reconstruct glacial-age environments on the Australian continent.

Here we provide new evidence for westerly wind regimes across glacial southeastern Australia. We confirm active transverse lunette deposition at c. 29 ka and c. 23-19 ka in the semi-arid Willandra Lakes, and identify aeolian sand incursions to Spring Creek on the temperate Western Victorian Volcanic Plains from c. 29 ka onward. The Spring Creek deposits contain a surprising quantity of sand-sized quartz given the basalt setting, which we propose to be allochthonous and likely transported some distance. The site lies more than 50 km east and south of dunefields which were active at the same time; we suggest that these contributed sediment via long distance transport.

We investigate the hypothesis for northward glacial expansion of westerly winds by combining our sediment records with aeolian particle transport simulations. We find that LGM near-surface winds were dominated by stronger, more focussed westerly air flow across southeastern Australia, compared with the more diffuse wind regimes of the present day. Our results suggest stronger potential for LGM eastward distal sand transport onto the basalt plains, coeval with enhanced aeolian activity in the semi-arid Australian dunefields. Our combined reconstruction of aeolian deposition and trajectory modelling confirms the extended LGM hypothesis, and indicates a northward migration of westerly winds over southeastern Australia during this period.

Late Quaternary glacial maxima at Lake Tennyson, New Zealand, and their climatic implications

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Mountain glacier extent is primarily determined by regional climate. Geomorphological evidence of past changes in glacier extent preserved in the landscape thus affords insight to past climate change. Here we present new constraints on the extent, timing, and climatic implications of glacial maxima at Lake Tennyson, New Zealand. High-resolution geomorphological mapping from a bespoke Light Detection And Ranging (LiDAR) survey, coupled with field-based investigations, reveals a well-preserved terminal moraine sequence extending c. 2 km from the southern lake shoreline. We constrain the timing of glacier retreat using cosmogenic ^{10}Be surface exposure dating applied to boulders on moraine crests. Preliminary results indicate the moraine sequence records the culmination of two glacial maxima of similar extent, first in oxygen isotope stage 4, and then at the end of the Last Glacial Maximum. Supported by numerical glacier model simulations, we provide quantitative constraints of the climatic conditions under which these former glaciers existed and commentary on the proposed drivers of late Quaternary glacial maxima.

Early glacier advance in New Zealand during the Antarctic Cold Reversal

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Glacial landscapes preserve records of past climate change. Investigating the glacier-climate system over the Late Quaternary provides information about past climate change and context for present day glacier response to climate warming. Using twenty-eight beryllium-10 (^{10}Be) surface exposure dates and snowline reconstructions, we present glacier fluctuations and climate changes for the Antarctic Cold Reversal in the Ahuriri River catchment, Southern Alps of New Zealand (44°7'50"S, 169°38'29"E). Prominent terminal and lateral moraine features from the upper right tributary of the Ahuriri River valley have exposure ages of 14.5±0.3 ka, 13.6±0.3 ka, and 12.6±0.2 ka, suggesting retreat of the glacier during the Antarctic Cold Reversal. Maximum elevation of lateral moraines (MELM) and accumulation area ratio (AAR) suggest snowline elevations at these ages were ≤700 m, ≤630 m, and ~360 m lower than today, respectively. This equates to air temperatures of ≤3.9, ≤3.5 °C, and 2.3±0.7 °C colder than today (1981–2010), assuming no changes in past precipitation. Ice-sculpted bedrock surfaces bound by a lateral moraine at nearby Canyon Creek have an age of 13.1±0.3 ka, indicating the moraine correlates with those in the Ahuriri upper right tributary. MELM and AAR reconstructions from the Canyon Creek suggest that snowline elevations at 14.5–13.6 ka were ≤500 or ~380 m lower than today, corresponding to air temperatures of ≤2.8 or 2.4±0.7 °C cooler than the present-day (1981–2010). Our results provide insight into the structure of the Antarctic Cold Reversal in the Southern Alps, showing that the largest glacier advance occurred at the start of this interval at c. 14.5±0.3 ka and was followed by gradual retreat. We hypothesize that the early cooling and glacier readvance in New Zealand at the onset of Antarctic Cold Reversal were triggered by a latitudinal shift of the Southern Hemisphere westerly wind belt.

Southern Hemisphere Glacier fluctuations during the past 70 kyr : Insights from offshore New Zealand

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Landforms produced by mountain glaciers are fundamental paleo-records of quaternary climate changes. However, the reconstruction of a full, and continuous paleo-records of glacier fluctuations based on glacigenic landforms is complex due to their random preservation because of erosion or overprinting issues. Here, we circumvent this limitation through producing a 70 kyr-long record of glacier fluctuations at the southern tip of the New Zealand's Southern Alps (44.5-46.2°S) from the study of deep-sea core TAN1106-28 (Solander Trough ; 48.4°S). High-resolution (≤500 years) geochemical (neodymium radiogenic isotopes, XRF) and mineralogical (including clay) investigations, coupled to a set of 52 radiocarbon dates, makes it possible to fingerprint the changes in source area (Fiordland versus Southland) of the sediment deposited at core site. We relate the changes in the sediment source to i) the long-term growth and decay of the Fiordland Icefield and, ii) to millennial-scale glacier fluctuations from MIS 4 to the Late glacial. Our Southern Alps glacier record reveals at least four periods of extension of the Fiordland Icefield well beyond the Te Anau, Manapouri and Monowaï proglacial lakes from ca. 70 to 30-28 ka. The largest ice advance is dated to ca. 44 ka and could represent the Local Last Glacial Maximum. From ca. 30-28 ka onward, the Fiordland Icefield significantly receded, likely forced by the rising obliquity, with the last fluctuations being recorded at around 17-15 ka at core site. This marine-based chronology for Southern Alps glaciers will be compared to cosmogenic surface-exposure moraines chronologies from New Zealand Central South Island (44°S), Kerguelen (49°S), Patagonia (42°S), and the Northern Hemispere records of glaciation. Finally, forcing factors, including latitudinal shifts of the austral westerlies and the Subtropical Front, will be discussed in the light of foraminifera-based paleoceanographic reconstructions at site TAN1106-28.

Vertebrate records, paleoclimatic and environmental features in MIS-3 and MIS-2 continental sedimentary beds of Uruguay, South America.

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The vertebrate record in continental sedimentary beds correlated to MIS-3 and MIS-2 at mid-latitudes of South America (SA) is analyzed in order to infer biotic responses to the climatic conditions. Concomitantly, the information provided by the fauna itself is useful to characterize both intervals (in particular the less known MIS-3 in terrestrial contexts of SA). Fossiliferous sedimentary beds (Sopas Formation) outcropping in northern Uruguay (30°08'16''S, 57°00'33''W to 32°13'16''S, 56°00'46"W), mostly originated under fluvial environments, are dated with several ^{14}C AMS (36,089 – 39,426 cal BP to 42,025 - 45,389 cal BP) and OSL ages included in the 45-28 ka interval. Vertebrates include migratory and aquatic avian taxa suggesting seasonal climate and mammal taxa (extant and extinct) related to open habitats, savannahs, woodlands, and gallery forests. It is emphasized the record of tropical to temperate mammals (such the tapir *Tapirus*, the marsh-rat *Lundomys molitor*, the capybara *Hydrochoerus hydrochaeris*, the ocelote *Leopardus pardalis*, the peccary *Parachoerus wagneri,* among others) into the MIS-3, which should have been more benign enough than the LGM, when different environments were able to house this fauna. Isotopic studies support C3/C4 grasslands, savannahs, open canopy wooded areas and gallery forests. A contrasting context is verified in late Pleistocene/early Holocene beds (Dolores Formation) outcropping in southern Uruguay (32°13'16''S, 56°00' 45"W), with gravitational and alluvial origin, including small lakes and ponds. Several ^{14}C AMS (28,565-27,930 cal BP to 11,117–11,121 cal BP) and OSL (30 to 8 ka) ages are available. This unit including MIS-2 allows analyzing its effect at biotic level. The prevailing cold and arid contexts are substantiated by the presence at this latitude of taxa living nowadays in arid to semiarid environments. The record in the southern Uruguayan Pampean area of some mammals currently inhabiting Patagonia, northwest and central Argentina, and even Andean highlands (such *Dolichotis*, *Galea*, *Microcavia*, *Chaetophractus*, *Lagostomus*, and *Vicugna*) could be explained by the predominance of open areas and cold climates favoured by the LGM. In both units, the mammalian assemblage provides evidence of not only local extinctions but also shifting range at genus and specific level highly related to climatic and habitats changes.

Paleoenvironmental and climatic inferences for the Late Pleistocene of Uruguay based on the native ungulate Neolicaphrium recens

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The knowledge of deposits belonging to MIS 3 in northern Uruguay (Sopas Formation), have been dramatically increased over the last decades. Different sources of information have provide evidences of warm, humid and seasonal climate, including open habitats, savannahs and woodlands. One of the species recently studied in order to acquire and compare environmental information is the proterotheriid (Mammalia, Litopterna) *Neolicaphrium recens*. This species is recorded in several localities from the Late Pleistocene of northern Uruguay as well in center and north of Argentina and southern Brazil. Specifically, we studied the dental microwear pattern and performed some estimations of body mass as a way to know its niche preferences. The results, obtained from specimens from different localities, showed a higher relative percentage of pits over scratches on the enamel surface, indicating a browser feeding habit. This kind of diet allow us to assume that the analyzed specimens consumed mostly leaves, shoots, buds and soft portions of trees and shrubs. These results are in agreement with those from isotopic analyses and support the prevalence of an open environment similar to a savannah. In addition, another important issue is the estimation of the body size (body mass) of this species, which is related to several ecological aspects, particularly type of physical environment and niche size. Calculations have been made by applying classical equations (based on several extant ungulates) on teeth and appendicular elements of *N. recens*. The last one are the most appropriate as they are directly linked to the support of the body and the relationship with the type of substrate (environment). Body masses ranging from 28 to 32 kg were obtained, which is similar to the Pampas deer *Ozotoceros bezoarticus*. *N. recens* has been also recorded in sediments from the Dolores Formation, outcropping in the South of Uruguay and deposited under LGM-related weather conditions (MIS 2). Exploring different ways to know the biology of this proterotheriid is important to understand its role in the communities, its niche preferences and its potential usefulness in the reconstruction of environments and their distribution during MIS 3-2.

Southern African dryland environments within SHeMAX: towards a terrestrial regional chronostratigraphic frameworks during the last global glacial.

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Subdivision of Quaternary environmental change in Southern Hemisphere drylands is usually arranged using Marine Oxygen Isotope Stages (MIS) as a framework. This overlooks the importance of terrestrial-based stratigraphic correlations and the opportunity to identify environmental shifts that were diachronous from global ice volume and/or subdued, or amplified responses to the forcing from global ice volume change. The Kalahari and the Namib Desert are the two key dryland areas of southern Africa, and these did not have ice cover during the last global glaciation. There is a range of archives and proxies in drylands from geomorphological proxies, such as sand dunes, former lake basins and former fluvial systems, through hydrological and hydrogeological precipitates and chemical signatures, to biological evidence within hyrax middens. This study aims to integrate these records to see if a (or a number of) terrestrial regional chronostratigraphic framework(s) can be identified. A lack of long near-continuous terrestrial sequences in drylands makes this a significant challenge, and an attempt to produce parasequences from the correspondence between nearby records is explored. In addition, recognising the modern climate diversity of southern Africa, a subdivision of four broad areas, the Namib Desert, the northern Kalahari, the southern Kalahari and the eastern fringes of the southern Kalahari, is used to explore potential sub-regional parasequences. A recent review of dunes and other geoproxies in dryland southern Africa suggests there have been seven broadly wetter intervals over the last ~190 ka, separated by relatively drier conditions, are seen, and their onset and cessation does not align with MIS. In this presentation, I focus on the character and extent of four identified wetter intervals ~64-43 ka, 34-25 ka, 32 to 16 ka and ~15 ka, during the period leading up to, and including the global Last Glacial Maximum, and discuss a range of hypothesised mechanisms for these hydroclimate shifts that have previously been identified.

Synchronous onset of the last glacial termination in the southern mid-latitudes

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Detailed comparisons of Antarctic and Greenland ice core records suggest an inter-hemispheric asynchrony of climate change at the end of the last glaciation. The extent to which this climate variability, its timing and regional synchrony affected the southern mid-latitudes remains uncertain. Here we present a compilation of multiples selected terrestrial proxy paleoclimate data from key mid-latitude Southern Hemisphere landmasses spanning the last glacial-interglacial transition, focusing on the onset of the last termination (T1). Our results show that synchronous deglacial climate conditions induced terrestrial environmental shifts in Tasmania, New Zealand's southern Island and western Patagonia at the beginning of T1, consistent with the commencement of the deglacial warming revealed by Antarctic ice records following the Last Glacial Maximum (LGM).

Pacific Island palaeovegetation change across the South Pacific Convergence Zone during the last glacial period

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The South Pacific Convergence Zone (SPCZ) is the most extensive rain band in the southern hemisphere and is a major driver of the prevailing climate of the South Pacific Region. Changes to the SPCZ at annual to millennial time scales have been measured from historical and palaeoclimatic proxies, respectively. While geochemical evidence has shown rapid shifts in the SPCZ during the last glacial period, evidence for ecological responses is limited. In order to address the role of MIS 3 climates in shaping the terrestrial ecosystems of the tropical oceanic Pacific islands, in periods unaffected by human activity, we present rare 'snapshots' of ecological changes on Tahiti (French Polynesia) and Upolu (Sāmoa). Fossil pollen, spores, and other fossil remains are examined from algal-rich sediments from both islands and are compared with geochemical measures of climatic change (e.g. XRF). Vegetation associations no longer present on these islands are observed, including the dominance of palm and sub-shrub vegetation more characteristic of some of the sub-tropical Pacific Islands. The ecological responses identified from these Pacific Islands provide evidence counter to the prevailing view that the tropical oceans buffered the ecological effects of abrupt climate changes during the last glacial period.

Millennial scale surface and deep water changes in the Benguela upwelling system during the last 45 ky

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The intensity and extension of the Benguela upwelling, along the southwestern coast of Africa, have been shown to vary on a millennial time scale during the last deglaciation. The changes in sea surface temperature in this region have been associated either with changes in the position of the ocean fronts in the SE Atlantic Ocean, themselves related to cold episodes in the North Atlantic, or to variations in the intensity of the upwelling, related to the intensity of the dominant winds.
Marine sediment cores from the Namibian margin, a region characterized by the upwelling of waters from 150-500 m depth, contain climate records showing these surface water variations. In particular, core MD08-3167, retrieved at 23°S and 1950 m of water depth on the Namibian margin during the 2008 RETRO cruise, has been shown to present high-resolution time series covering the last 40 ky. Stable isotopes ($d^{18}O$ and $d^{13}C$) and Mg/Ca have been measured in the planktonic foraminifer *Globigerina bulloides*, which may be assumed to thrive in upwelled waters. The records show a very marked, rapid warming of more than 4°C at the start of the last deglaciation, coinciding with the beginning of Heinrich Stadial (HS) 1 in the North Atlantic. However, the previous three HS show a different pattern, with subdued variability and evidences of cooling and freshening during some of them. Planktic foraminiferal counts and $d^{18}O$ measured in the deeper-dwelling foraminifera *Globorotalia inflata* rather suggest enhanced upwelling driving augmented productivity between 28 – 19 ky BP, that may have been driven by enhanced trade winds and obscured glacial millennial scale variability.

Neolicaphrium recens in the Late Pleistocene of Uruguay, new records and use of CAT in the study of young specimens

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South America evolved as an isolated system for a long time during the Cenozoic, allowing the radiation of very diverse groups of native ungulates (SANUs). The Family Proterotheriidae (Litopterna, Panameriungulata) is one of those SANUs, recording the only single species Neolicaphrium recens in the Late Pleistocene. This taxon has shown a wide latitudinal distribution, from the center-north of Argentina, South of Brazil until southern Uruguay. In this contribution, we present new specimens of N. recens recently found in deposits of the Sopas Formation (Late Pleistocene, northern Uruguay) and discuss the usefulness of the computed tomography (CAT) as a powerful tool, helping in the descriptions and study of juvenile specimens. The new records consist of a an almost complete mandible with left dp2-dp4 and m1 erupting and right p1, dp2-dp4, and m1 erupting (MNHN 3186); right calcaneus and astragalus, and two mandible fragments with right p3-m2 and left m1-m3 (m3 erupting) (FC-DPV 3427); a right mandible fragment with p3-m2 (CPG 93-2); a left M2 (CPG 24-2) and a right astragalus (CPG 122-1). The tomographies performed on the specimen FC-DPV 3427 revealed that it did not have any unerupted tooth inside the bone, but the remains are too fragmentary and have a really poor preservation. On the other hand, for the specimen MNHN 3186, studied under the same conditions, the tomography revealed that the m2 on both right and left sides are present inside the alveolus, very close to the surface, near eruption, and with no evidence of the presence of the m3, even having little space for its development. The obtained images are very convincing, allowing to determine the sequence and time (quite long) of dental eruption. Moreover, these specimens and techniques allow us to improve the morphological knowledge of N. recens at a craniomandibular (specially dental) and postcranial level, being very important the understanding of the ontogeny. N. recens is currently the native subject of several approaches in order to assess a complete set of information for the reconstruction of environments and climates during the Late Pleistocene at middle latitudes in South America.

Paleoceanography of the Southern Ocean during the last glacial period

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We have compiled published Sea Surface Temperature (SST) records from 30-60°S to understand the paleoceanographic changes in the Southern Ocean (SO) over the last 75 ka (Anderson et al., 2021). Here we will focus on the Last Glacial period from 35-15 ka, in line with the objectives of the SHeMAX project.

We included SST from a range of proxies including alkenones, microfossil assemblages and transfer functions, and Mg/Ca foraminifera. We only used records with sedimentation rates >2.5 cm/kyr and recalibrated the radiocarbon dates from each of these sites and synchronised the sea surface temperature (SST) records using a range of tie points with the Antarctic Ice Core Chronology 2012. SST anomalies were determined by subtracting the average SST for each individual core from the period of 59-27 ka (MIS3 average) in order to focus on relative temperature changes. The records were then combined to form a SO stack of SST anomalies as well as Atlantic and Indo-Pacific basin stacks of SST anomalies.

The normalised SST anomaly stacks from the Atlantic and Indo-Pacific show strong similarities in amplitudes of SST changes across the SO. While there is a general cooling trend from MIS5a through to the last glacial period, there is a slightly anomalous cool period during 50-40 ka immediately prior to a 35 ka. Between 35-18 ka the SST display temperature anomalies of 0 to +1°C. On millennial scale, the SO SST stacks show similar temperature variability with the ice cores, with warmer periods of SST aligned with Antarctic Isotope Maxima (AIM), for example between 30-28 ka aligned with AIM4 (Heinrich Stadial 3). At the end of the glacial period the deglacial in the SO is characterised by abrupt warming, synchronous with the timing of Antarctic temperature changes.

Transient response of the ocean carbon cycle during the last deglaciation

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We used an ocean carbon cycle model that was imposed on the output of the climate model MIROC 4m to explore the mechanisms of transient changes in the ocean carbon cycle during the last deglaciation. The model experiment showed that atmospheric partial pressure of carbon dioxide (pCO2) increased during the Heinrich Stadial 1 (HS1) and the Younger Dryas (YD) and decreased during the Bølling-Allerød (BA). In other words, the ocean becomes a source of carbon during the HS1 and YD and a sink during the BA. The atmospheric pCO2 rise during the HS1 was found to be largely attributable to an increase in sea surface temperature (SST), especially in the Southern Hemisphere. During the BA, an increase in surface alkalinity associated with the recovery of the Atlantic meridional overturning circulation (AMOC) contributed to the decrease in surface ocean pCO2. On the other hand, a decrease in CO2 solubility due to temperature changes partially compensated for the pCO2 decrease. During the YD, an increase in SST again contributed to the increase in surface ocean pCO2. The model experiments showed that changes in the oceanic carbon cycle associated with changes in AMOC may explain about a quarter of the real atmospheric CO2 during deglaciation. It has remained difficult for us to simulate the rapid centennial-scale changes in atmospheric pCO2 indicated by ice core data. Previous studies have suggested that changes in the strength of mixing in the Southern Ocean due to changes in westerly winds and stratification may have contributed to the rise in atmospheric pCO2 during the deglaciation. Therefore, reproducing environmental changes in the Southern Ocean under paleoceanographic data constraints may contribute to accurately simulating the rapid increase in atmospheric pCO2 during the deglaciation.

Carbonate Counter Pump and upwelling strengths in the Indian sector of the Southern Ocean during TV-MIS 11 and their impacts on the carbon cycle

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During the glacial-interglacial cycles of the past 800 000 years (800 ka), atmospheric CO_2 concentrations (pCO_2) have changed with amplitudes of 50-100 ppm, the fastest increases being registered during glacial terminations (T). Biological productivity in the Southern Ocean plays an important role in such pCO_2 variations, impacting the ocean-atmosphere exchanges of CO_2 through changes in Biological Carbon Pump strength that includes the Soft Tissue Pump (i.e., the net downward flux of phytoplanktonic carbon that draws down pCO_2) and the Carbonate Counter Pump (CCP - i.e., the export of planktonic carbonate that influences the surface-to-depth alkalinity gradient and increases pCO_2).

Existing paleoclimate studies usually focus on the Soft Tissue Pump and demonstrate that its weakening may contribute to the increase in pCO_2 during Terminations. Not much is known about the CCP due to the lack of high-resolution studies in the SO based on both, micropaleontological and geochemical approaches.

Among the last 9 interglacials, Marine Isotope Stage (MIS) 11, that follows TV, is the longest and is characterized by an exceptional 30 ka-plateau of pCO_2. It registers the strongest global productivity signal and the highest marine carbonate export production.

Here, we present micropaleontological (coccolith, planktonic foraminifera) and geochemical ($CaCO_3$, Ca_{XRF}, $d^{13}C_{N.\ pachyderma}$) data from sediment core MD04-2718 retrieved in the Polar Front Zone of the Indian Ocean, covering MIS 12-10. We compare our results with published records from sediment and ice cores, to reconstruct past changes in CCP and upwelling strength, and understand their leverage on the ocean-atmosphere portioning of CO_2.

We demonstrate that the sharp increase in pCO_2 during TV is associated with enhanced deep-water ventilation. Strengthened CCP is observed later, during MIS 11, and is probably the consequence of higher sea surface temperature and nutrient availability due to the reinvigoration of Southern Ocean upwelling, leading to increased coccolith export production. The low eccentricity signal recorded during MIS 11 might have additionally strengthened the CCP, exerting a specific control on *Gephyrocapsa* morphotypes. Together with a strong global biological productivity these synergistic mechanisms may have permitted to shape the long pCO_2plateau characteristic of MIS 11.

Chronostratigraphy of the Late Pleistocene fluvio-aeolian succession in the Polish part of the European Sand Belt

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The Polish part of the European Sand Belt (ESB) is a remarkably interesting remnant of the Late Glacial aeolian accumulation. It is covered with extensive dune fields as well as individual dunes related to numerous river valleys. In the last few years has been carrying out multi-proxy studies of phases of aeolian activity in the ESB at over 50 profiles including fluvio-aeolian succession with palaeosols. The research results obtained so far indicate, first of all, the high sensitivity of the aeolian environment to environmental changes, including climatic changes and oscillations.

The currently collected results, which consist over than 300 OSL dates and about 70 ^{14}C results as part of the implemented project allow for verification the existing models of aeolian deposition development which they assumed that dune-forming processes took place mainly during the late-glacial cooling of the climate (the Oldest, Older and Younger Dryas). These dune-forming periods were assigned a different rank (the formation of dunes or their transformation). These phases were interrupted by the Bølling and Allerød interstadials, during which soil-forming processes took place.

A comparison of the existing models with new research results from marine sediments and ice cores from Greenland and the results from the western part of ESB reveals large discrepancies, which are probably not only due to a different position in within the ESB. Their causes can be found in stratigraphic models, which are mostly based on a few, often uncalibrated, results of radiocarbon dating obtained from individual sites, or too few samples taken from opencasts without checking them with other methods. Also, new research results obtained from the Polish part of ESB indicate that both in reservoir sediments and in the fluvio-aeolian succession, it is possible to identify climatic oscillations known from the Greenland ice cores.

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Atmospheric dynamics, surface Pacific conditions and the North American ice sheet at the Last Glacial Maximum

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Surface ocean conditions and atmospheric dynamics can affect the surface mass balance of remote ice sheets via their influence on heat and moisture transport. Here, we use the FAMOUS-ice coupled climate-ice sheet model to simulate the Last Glacial Maximum. The model was run hundreds of times to produce a large ensemble that captures a range of uncertain model inputs (parameter values). We investigate the range of simulated atmospheric circulation patterns, their relationship to sea surface conditions in the North Pacific and the interactions with the North American ice sheet (e.g. through the effects on ice sheet surface mass balance).

The hydrological variability from the Last Glacial Maximum to Holocene transition in the central Mediterranean from speleothem stable isotopes

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The last deglaciation (Termination I) saw rapid northern latitude temperature changes and ice-sheet loss, coupled with changes in the Atlantic Meridional Overturning Circulation. However, the modes, timing and sustaining mechanisms that propagated these changes to the Mediterranean region are far from well understood. Here, we compare two high-resolution stalagmite $\delta^{18}O$ time series from Southern Italy: one from Sicily (new data) and one from Puglia (Columbu et al., 2022). Both records show a substantial agreement in the main changes and steps in $\delta^{18}O$ patterns (within uncertainties of the two age models), which indicates synchronous changes in local hydrology. However, between 14.2 and 13.2 ka the two records show prominent antiphasing, with drying in Sicily occurring at a time of wetter conditions in Puglia. This suggests the presence of a thus-far-undetected strong atmospheric gradient at a specific phase of the glacial-to-interglacial transition. This requires further investigations using other highly resolved proxy data to confirm these data and evaluate the regional extent of this pattern.

Parameter ensemble simulations of the North American ice sheet and climate at the Last Glacial Maximum with Famous-BISICLES

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Testing the ability of coupled climate-ice sheet models to simulate past ice sheet can provide a way to evaluate the models and ground truth projections. One example is the Last Glacial Maximum (LGM), when huge ice sheets covered the Northern Hemisphere, especially over North America. Here, we performed ensemble simulations of the North American ice sheet and climate of the LGM with an ice sheet-atmosphere-slab ocean coupled model Famous-BISICLES. The model consists of an atmospheric general circulation model Famous (Smith et al. 2008) and an ice sheet model BISICLES (Cornford et al. 2013). The atmospheric model reproduces the surface mass balance of the modern Greenland ice sheet reasonably well (Smith et al. 2021). We conducted more than 200 members of ensemble experiments varying 17 parameters associated with climate, ice albedo, ocean and ice dynamics. The simulated results are first evaluated against LGM global temperature. These simulation results are then used to explore effects of individual uncertain parameter as well as to evaluate parameter spaces that reproduce the ice sheet and climate reasonably well. We will show the role of individual parameter on the performance of the North American ice sheet. In addition, we discuss how the uncertainties in the LGM global temperature can affect the maintenance of an ice sheet. Ensemble simulations of modern Greenland and climate are also performed with the same model (Lang et al. in prep) and the results will be compared to our LGM simulations together with some simulations of the last deglaciation.

The last deglaciation in the SW Iberian margin: changes in the Atlantic surface and Mediterranean bottom waters.

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The transition from the Last Glacial Maximum to the Holocene interglacial period is marked by abrupt global changes in which ocean thermohaline circulation, ice sheets and atmosphere interacted. Mediterranean overturning circulation and thus Mediterranean outflow were strongly influenced by these changes and might even have played a role by exporting heat and salt to the North Atlantic. The gulf of Cádiz Contourite Depositional System is characterized by the presence of two sandy contourite layers, corresponding to periods of reduced Atlantic Overturning Circulation (AMOC) during late Heinrich stadial 1 and Younger Dryas. In this work we present new multiproxy record for last 30ka from a sediment core located in the main branch of Mediterranean overflow. Planktic foraminifera assemblages have been used to reconstruct North Atlantic-influenced sea surface temperatures (SST), and Mg/Ca in benthic foraminifera to reconstruct Mediterranean overflow-influenced seawater bottom temperature (SBT).

Results from planktic foraminifera are well correlated with what is recorded in nearby sites, marked by an abrupt SST drop during Heinrich event 1 and relatively high SST during LGM. Sea bottom temperatures raised gradually from Greenland stadial 3, as observed in Greenland ice temperature records, showing relatively warm values during LGM as noticed in SST. We suggest that this synchronism between Mediterranean deep water and Greenland air temperatures trends can be explained by the atmospheric teleconnection between both regions. Cool air temperatures in Greenland are transferred to the Mediterranean through winter winds that caused surface water cooling and sinking to the deep Mediterranean. This long-term warming trend that reflects the average temperature of Mediterranean deep water was punctuated by by two events of higher temperatures at times of Sandy Contourite layers deposition (Late Heinrich stadial and late Younger Dryas). These pulses of heat and salt export to the North Atlantic just before the onset of AMOC restoration are consistent with the hypothesized Mediterranean Outflow contribution during Terminations.

Late Pleistocene deglaciation and Scandinavian Ice Sheet dynamics in NE-Germany and NW-Poland: new results from surface exposure dating

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Age compilations documenting the late Quaternary dynamics of the Scandinavian Ice Sheet (SIS) have highlighted that last glaciation advance and retreat timings varied significantly across different SIS sectors. Resolving these issues has been difficult as there are still some key areas with contradictory evidence and/or gaps in the record due to a lack of absolute age information. Among the regions where significant uncertainties persist is the North-German Plain, in spite of representing one of the classical landscapes for glacial research since the mid-19th century. As a consequence, there is an ongoing lively debate around a series of SIS research questions including: (a) if and how far a potential mid-Weichselian ice advance extended into northern Germany; (b) whether or not the local maximum of the Odra ice stream pre-dates or coincides with the overall SIS maximum at c. 21 ka; and (c) at what time did the LGM retreat commence and when was the deglaciation of the German mainland completed? Here we present new information on the regional deglaciation history of the SIS based on a total of 72 CRN surface-exposure-ages (^{10}Be) from glacial landforms between the main LGM ice margin and the Baltic Sea coast. We find that stagnation and initial ice retreat from the main LGM limit commenced as early as 23.0 ± 1.4 ka, while the Frankfurt ice limit further to the north was abandoned around 19.9 ± 3.8 ka. Following a major re-advance to the Pomeranian ice margin yielded a mean age of 17.0 ± 1.7 ka, while glacial boulders from the Islands of Rügen, Usedom and Wollin, deposited just before the SIS retreated into the Basltic Sea Basin, returned a mean age of 15.9 ± 1.5 ka. Our record indicates that the post-LGM deglaciation of the North German Plain, referring to the final SIS retreat from the Pomeranian moraine to the present-day coast, and covering a recession of c. 130 km, occurred relatively rapidly and was probably accelerated by widespread glacier calving into large proglacial lakes.

A multi-model assessment of the onset of the last deglaciation

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At the onset of the last deglaciation, beginning ~19 thousand years ago, ice sheets that covered the Northern Hemisphere at the Last Glacial Maximum started to melt, Earth began to warm, and sea levels rose. This time period is defined by major long-term, millennial-scale, climate transitions from the cold glacial to warm interglacial state, as well as many short-term, centennial- to decadal-scale warmings and coolings of more than 5 °C, sudden reorganisations of basin-wide circulations, and jumps in sea level of tons of meters. Long transient simulations of the deglaciation have been increasingly performed to better understand the long and short term processes, examine different possible scenarios, and compare model output to observable records. The Paleoclimate Modelling Intercomparison Project (PMIP) has provided a framework for an international coordinated effort in simulating the last deglaciation whilst encompassing a broad range of models and model complexities. This study is a multi-model intercomparison of 17 simulations of the last deglaciation from nine different climate models. Unlike other multi-model intercomparison projects, these simulations do not follow one particular experimental design but follow an intentionally flexible protocol suitable for all participants. The design of the PMIP protocol provides the opportunity to compare results from models using different forcings and examine a variety of scenarios, hence, representing the range of uncertainty in climate predictions of the time period. One particularly challenging choice to make in the experimental design is how to incorporate the resultant freshwater flux from the melting ice sheets. This research focuses on the divergence between climate trajectories in the simulations as a result of the meltwater scenario preferred by the modelling groups as well as other experimental design choices and their impact on the onset of the deglaciation. These results provide a better understanding of modelling this time period as well as model biases and uncertainty with respect to deglacial forcings and the observable proxy records.

A fast slow model for glacial interglacial cycles since the Mid-Pleistocene Transition

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A new simple approach inspired by MacAyeal (1979) is used to explain the time asymmetric saw tooth shape of glacial interglacial cycles. A simple model with slow fast dynamics, where the global ice volume is taken to be a function of two independently varying parameters, the solar insolation and 'alpha', a secondary control parameter, is used. The study investigates how dynamics of the system are altered due to the addition of the second control parameter, which changes the geometry of the slow manifold to a partially folded surface. The pleated cusp geometry allows the system to exhibit both smooth changes and sudden discontinuous transitions from one stable solution to another, producing the gradual increase and sudden decrease in ice volume observed in the paleoclimate record. The control parameter alpha is suggested to be related to the internal dynamics of the climate system, proposed to be a measure of the glacial oceanic interaction, which varies due to glacial isostatic adjustments of the bedrock. The Mid-Pleistocene transition is suggested to occur as a result of northern hemisphere glaciers exceeding a critical threshold, which allows alpha to become larger, causing 100kyr glacial interglacial cycles of higher amplitude than prior to the MPT.

High precision δ13C of atmospheric CO2 record for the penultimate deglaciation and last interglacial

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The stable isotopic ratio of CO_2 ($\delta^{13}C$-CO_2) measured in ice cores can be a useful tool for deciphering which of the carbon sources and sinks are responsible for past changes in atmospheric CO_2. A record of $\delta^{13}C$-CO_2 across the penultimate deglaciation and last interglacial period was constructed by Schneider et al. 2013 and presented novel insight into the potential carbon cycle fluxes affecting CO_2
across Termination II. We are reconstructing $\delta^{13}C$-CO_2 from a large diameter ice core from the Allan Hills, Antarctica. The core provides an opportunity to construct a more detailed record, roughly doubling the resolution, as well as increasing the precision to ~0.03 ‰. With this detailed record, we will be able to investigate outstanding questions about Termination II, such as: 1) What is the $\delta^{13}C$ during the penultimate glacial maximum, and can we better understand the long-term carbon cycle processes influencing atmospheric CO_2? 2) Do we see a change in $\delta^{13}C$ associated with centennial-scale CO_2 events that have been observed during the penultimate deglaciation? 3) Can a higher resolution $\delta^{13}C$ dataset provide further information about the 5000-year lag between CO_2 and temperature inferred from the EPICA Dome C ice core? Finally, a detailed $\delta^{13}C$-CO_2 record can inform our understanding of the interplay between millennial- and orbital-scale climate variability and how they interact to produce a termination.

Catchment vegetation and erosion controls soil carbon cycling in SE Australia during two Glacial-Interglacial transitions

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Soil Organic Carbon (SOC) represents up to 80% of the terrestrial carbon pool. However, it is highly debated if soil carbon is a net atmospheric carbon source or sink. This is mainly due to a paucity of information on the fate of SOC during soil erosion, which affects oxidation during the storage, transportation, and final deposition of SOC. The Southern Hemisphere may play a dominant role in the global SOC - atmosphere carbon cycle, since changing climates can cause the expansion or contraction of terrestrial biomass across vast continental areas, for example in temperate to semi-arid Australia.

Here, we investigate the interplay between catchment erosion (quantified by means of uranium isotopes), vegetation cover (pollen), the wetland response (diatoms), and lake carbon accumulation on glacial/interglacial time scales in south-eastern Australia. The analyses are applied to the sediments of Lake Couridjah (Thirlmere Lakes) SW of Sydney. The recovered lake sediments cover the time interval between ~135 ka and 107 ka, and between ~17.6 ka and present day. This offers an outstanding opportunity to study SOC cycling across different glacial/interglacial boundary conditions.

Partial Least-Square Regression (PLSR) analyses reveal robust phase-relationships between catchment erosion, vegetation density, and carbon and nitrogen cycling during both glacial-interglacial complexes. The data imply that the density of the catchment's sclerophyll mid- to understorey vegetation, and not the amount of rainfall, has the dominant effect over catchment erosion, and over SOC storage in the catchment. Wetter and warmer conditions promote the expansion of dense sclerophyll vegetation, reducing (increasing) catchment erosion while simultaneously increasing (decreasing) SOC storage as well as lake productivity and lake carbon storage. This would imply a positive relationship between warmer and wetter climates and atmospheric CO_2 sequestration in the Thirlmere catchment.

A Bayesian Multiproxy Approach to Regional Age Models

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Previously developed software packages that generate probabilistic age models for sediment cores are designed to use either age proxies (e.g., radiocarbon or tephra layers) or stratigraphic alignment (e.g., of benthic δ^{18}O) and cannot combine age inferences from both techniques. Furthermore, many radiocarbon dating packages are not specifically designed for marine sediment cores and default settings may not accurately reflect sedimentation rate variability in the deep ocean, requiring subjective tuning of parameter settings. Here we present a new technique for generating Bayesian age models and stacks of ocean sediment core data, implemented in a software package named BIGMACS (Bayesian Inference Gaussian Process regression and Multiproxy Alignment of Continuous Signals). BIGMACS constructs multiproxy age models by combining age inferences from both radiocarbon ages and δ^{18}O stratigraphic alignment and constrains sedimentation rates using an empirically derived prior model based on 37 ^{14}C-dated ocean sediment cores (Lin et al., 2014). BIGMACS also constructs continuous benthic δ^{18}O stacks via a Gaussian process regression, which requires a smaller number of cores than previous stacking methods. This feature allows users to construct stacks for a small hydrographic region that shares a homogeneous deep water δ^{18}O signal, while leveraging radiocarbon dates across multiple cores. Thus, BIGMACS efficiently generates local or regional stacks with smaller uncertainties in both age and δ^{18}O than previously available techniques.

Global and regional effects of Hudson Bay closure during deglaciation periods

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During the Quaternary, the Hudson Bay switched between closed (covered by ice sheet) and open (ice sheet-free) condition due to large variations of ice sheets. However, how the closure and opening of the Hudson Bay have affected the local and global climates is still poorly understood. Using the LOVECLIM1.3 model, here we investigate the global and regional effects of Hudson Bay closure at the beginning of each deglaciation period of the last 800 ka. Sensitivity experiments are performed at nine selected dates at the early stage of the deglaciation periods which are characterized by large Northern Hemisphere (NH) ice sheets, relatively low CO2 and different combinations of astronomical parameters. Two experiments are performed at each date, one with the Hudson Bay open and another with the Hudson Bay closed. Our model results show that the closure of the Hudson Bay could lead to a strengthening of the Atlantic Meridional Overturning Circulation (AMOC), which in turn leads to a warming in the Northern Hemisphere with notable warming in the Labrador Sea and northeast North Atlantic, a cooling in the Southern Hemisphere and a northward shift of the Inter-tropical Convergence Zone (ITCZ). In addition to the large-scale climate changes related to the modification of AMOC, the closure of Hudson Bay also has a great effect on regional climate. For example, there is a cooling over the Hudson Bay and over the southeast of Greenland. Our results also show that the effect of the Hudson Bay closure depends on background climate conditions, and it could weaken or slightly reinforce the effect of the ice sheets for different astronomical configurations.

Simulating the chain of events of the last deglaciation using its ice sheet meltwater history

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Despite being one of the most thoroughly studied periods in our planet's history, the last deglaciation remains an active topic of study. In the early phase of deglaciation, Heinrich stadial 1, increasing greenhouse gases and mid-high latitude Northern Hemisphere orbital forcing did not lead to a significant warming and it took another six to seven thousand years before this cold period ended. A sequence of abrupt transitions followed with the Bølling–Allerød warming, the Younger Dryas cooling and the Holocene warming. Changes of Atlantic Meridional Overturning Circulation (AMOC) regimes are widely thought to be the origin of such climate disruptions, but exactly what role they play remains unclear.

Reproducing the complex chain of rapid climate-ocean events in a general circulation model has proven to be particularly challenging. Abrupt climate changes may only be obtained in a small window of opportunity, and such delicate balance is hard to strike considering the uncertainty inherent within reconstructions of the palaeo-environment. In particular, the ice sheets 'reconstructions' have a strong influence on the North Atlantic climate but are amongst the least well constrained. Different geometry and meltwater discharge histories from ice melting/calving produce widely varying wind patterns (including the position of the atmospheric jets) and ocean currents.

To investigate the sensitivity of a climate model to the ice sheet layout and meltwater flux, we produced a series of transient deglacial simulations using different combinations of ice sheets and transient freshwater forcing. The simulations manage to catch significant disruptions of the climate, but the timing of the events remains variable depending on the input. We identify the main drivers of changes in our model to be the geometry of the Laurentide ice sheet and the meltwater from the Eurasian ice sheet. The uncertainty surrounding the history of the Eurasian ice sheet and its meltwater discharge is a real limitation for any last deglaciation experiment.

Biomarker analysis of a marine sediment core (Northern Svalbard) reveals new insights into post-glacial permafrost carbon release

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During the last post-glacial warming, the Arctic region experienced a major reorganization of the entire cryosphere. In particular, the Bølling-Allerød interstadial (B-A; ca. 14.7-12.8ky BP) was characterized by a significant ice loss from the Eurasian Ice Sheet, associated with a period of rapid sea level rise (Meltwater Pulse 1A, MWP-1A; ca. 14.7-14.3ky BP). However, how the land-ocean connection and in particular the fate of the terrestrial cryosphere were ultimately affected by this rapid climatic change remains poorly understood.

We present the multiproxy analysis of a marine sediment core (HH11-09GC) from the upper slope of Nordaustlandet (Svalbard archipelago), encompassing the last 30ky. Our results reveal that, after a phase influenced by the release of clastic material eroded by the Svalbard Barents Sea Ice Sheet (SBIS) during the Last Glacial Maximum and the early deglaciation, biospheric terrestrial carbon became the dominant component of the organic material deposited along the margin, in phase with MWP-1A and with a corresponding peak in the sedimentation rate, exceeding 1 mm/y.

We initially narrowed the possible origin of this atypical deposit down to four different hypotheses: (1) local Arctic material from Svalbard supplied via glaciers, (2) an unprecedented flooding event from the Baltic/Kara continental shelf, (3) the subglacial transport of land-derived material beneath the SBIS and (4) the advection and melting of sediment-laden sea ice via the Transpolar Drift. Collectively, the age of the terrestrial compounds, the biomarkers fingerprint and the sedimentological characteristics suggest sea ice transport of terrigenous material. We envision that during MWP-1A the intensified erosion of coastal Pleistocene Ice Complex Deposit from an unidentified source along the Siberian margin yielded massive amounts of sediment-laden sea ice; in addition, the strengthening of the Atlantic Water inflow through the Fram Strait during the B-A likely sustained a high melting rate of sea ice in the region.

Our findings provide a novel understanding of deglacial permafrost release in a rapid warming and sea level rise scenario. Furthermore, we provide evidence of how long-range transport and thawing of sediment-laden sea ice from coastal regions can impact the depositional characteristics at the gate of the Arctic Ocean.

Deglacial climate changes as forced by ice sheet reconstructions

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During the Last Deglaciation, the climate evolves from a cold state at the Last Glacial Maximum at 21 ka with large ice sheets, to the warm Holocene at ~9 ka with reduced ice sheets. The deglacial ice sheet melt can impact the climate through multiple ways: changes of topography and albedo, bathymetry and coastlines, as well as fresh water fluxes. In the PMIP4 protocol for deglacial simulations, these changes can be accounted or not depending on the modelling group choices. In addition, two ice sheet reconstructions are available (ICE-6G_C and GLAC-1D).

Using the iLOVECLIM model of intermediate complexity, we evaluate the impact on climate of these boundary changes related to ice sheet evolution. We show that the two reconstructions yield the same warming to a first order, but with a different amplitude (3.9°C with ICE-6G_C and 3.8°C with GLAC-1D) and evolution. We obtain a stalling of temperature rise during the Antarctic Cold Reversal (from ~14 ka to ~12 ka) similar to proxy data only with the GLAC-1D ice sheet reconstruction. Accounting for changes in bathymetry in the simulations results in a cooling due to a larger sea ice extent and higher surface albedo. Finally, fresh water fluxes result in AMOC drawdown, but the timing in the simulations disagrees with proxy data of ocean circulation changes. This questions the links between reconstructed fresh water fluxes from ice sheet melt and recorded AMOC weakening and their representation in models.

Deglacial oceanic CO2 outgassing in MPI-ESM

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Ocean-atmosphere CO2 exchange plays an essential role in the atmospheric CO2 variations at the glacial-interglacial time scale. Extensive studies have suggested that during the last deglaciation, the oceanic CO2 outgassing results from the interplay between physical (e.g. ventilation, sea-ice cover) and biogeochemical (e.g. biological pump, carbonate pump) processes. To quantify their contributions to ocean-atmosphere CO2 flux, modelling studies have been conducted for the Last Glacial Maximum (LGM) and/or the last deglaciation using Earth System Models of different complexity. Given the complex nature of the interplay of Earth system processes driving the global carbon cycle, as well as the limitations of the models, it is still challenging to simulate the LGM and deglacial ocean states that capture the major features of proxy data. A particular example is that most models in the Paleoclimate Modelling Intercomparison Project 4 (PMIP4) feature an Atlantic Meridional Overturning Circulation (AMOC) with a deeper upper cell during LGM than the pre-industrial, the opposite of the proxy data, and therefore hinder the storage of carbon in the deep ocean.

To address this challenge, we conduct two types of simulations with the Max Planck Institute Earth System Model (MPI-ESM) using a ‘prognostic CO2’ set-up; that is, the global carbon cycle prognostically computes atmospheric CO2, while the radiation calculation uses prescribed CO2 from ice core measurements. First, to examine the impact of ocean circulation on the LGM ocean carbon sequestration, we simulate two LGM AMOC states by model tuning: one with a deeper upper cell and the other with a shallower upper cell than the pre-industrial state. We evaluate the LGM simulations with a comparison to sea surface temperature, benthic CO_3^{2-}, $\delta^{13}C$ and $\Delta^{14}C$. Next, we conduct transient deglaciation simulations, forced by reconstructions of orbital parameters, ice sheet and dust deposition. We present results from the deglaciation simulation and focus our analysis on the above-mentioned oceanic CO2 outgassing mechanisms. We also compare the model results of the prognostic CO2 set-up to a previous simulation where CO2 is prescribed for both radiation calculation and the global carbon cycle to reveal the different model behaviours linked to the modelling strategy.

Polar and Arctic Fronts movement and attendant water masses changes in the North Atlantic during the last glacial cycle

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Past studies using planktonic foraminiferal assemblages in the North Atlantic were mainly focused on narrow regions. As a result, such data are scarce, especially from the North Atlantic transition region (NATZ) and the western subpolar gyre (SPG) during the last glacial cycle. Here, we report planktonic foraminiferal assemblages in conjunction with oxygen isotope and ice-rafted detritus (IRD) data from three sediment cores (i.e., Hu90-08, Hu71-377, and IODP Site U1313) covering a latitudinal transect between the SPG and subtropical gyre (STG). These data suggest that the Polar front (PF) and Arctic front (AF) were located south of the cores Hu90-08 and Hu71-377, while the subarctic front (SAF) was situated south of site U1313 during last deglaciation. An increase in the transitional water mass species (i.e., Globigerina bulloides and Globigerinoides inflata) suggests that the core Hu71-377 was mainly affected by the North Atlantic Current (NAC), and the SAF was located north of Hu71-377 during the MIS3. Simultaneously, cores Hu90-08 and U1313 recorded cold (40-27 ka) and warm (60-40 ka) periods. During the last glacial maximum (LGM), the PF moved southward to 45°N, and the heat transported by the NAC accumulated south of the IRD-belt south of the PF, resulting in a relatively warmer sea-surface surrounding the site U1313. Consequently, a significant hydrological difference appeared between the STG and SPG during the LGM. Compared with the eastern SPG, the western SPG (near Newfoundland Basin) and STG were generally warmer during the MIS5. However, the abundance of planktonic foraminifers in the Newfoundland Basin core Hu90-08 shows that the western SPG was affected by seasonal subpolar water masses during the MIS5e (~124-120 ka) indicating a transient southward movement of the PF and AF. Contemporaneously, a stable warm climate prevailed at Site U1313, which was affected by warm subtropical water mass throughout the MIS5e. Moreover, our data shows that the western SPG was influenced by polar water but the STG was influenced by subpolar water during termination II. Therefore, our data suggest an identical transformation and movement of the surface water masses in the western SPG and NATZ during terminations I and II.

Coccolithophores responses during Termination II: perspectives on their potential within the ocean carbon cycle

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Coccolithophores are single-celled eukaryotic algae capable of capturing carbon dioxide (CO_2) through photosynthesis, and fixing carbon in their calcite exoskeleton (coccosphere). Through their vital processes, they can significantly impact the atmosphere-ocean CO_2 exchanges and the global carbon cycle, influencing Earth's climate system since geological time.

The aim of this project is to deepen on coccolithophores' role within the ocean carbon cycle during Termination II (i.e., Marine isotope stage 6/5e transition), and to investigate their responses to the deglaciation phase. To do so, the coccolithophore fossil remains (i.e., nannofossils) from the International Ocean Discovery Program (IODP) Site U1501C (South China Sea) have been analyzed along an interval spanning from 155 to 70 kyrs, thus encompassing the Termination II. These data were compared with 6 sites distributed in the Pacific, Atlantic, and Indian oceans in order to observe at global level the study of coccolithophore response to climate variations in terms of diversity, primary productivity and carbonate production.

At Site U1501C, the data on calcareous nannofossil absolute and relative abundances, primary productivity, and coccolith-derived calcium carbonate production allowed reconstructing both the biological and carbonate pumps efficiencies at a local scale. We document an increase in abundance of the heavily-calcified species (*Helicosphaera* spp., *Syracosphaera* spp., *Calcidiscus leptoporus*) together with increased primary productivity and calcite production at MIS 6/5 boundary suggesting that coccolithophores accelerated both the biological and carbonate pumps in response to the glacial/interglacial transition in South China Sea.

The data derived from other sites highlighted similar results in most of the areas, documenting an increase in the nannofossil absolute abundances and coccolith-derived calcium carbonate production during the glacial/interglacial transition, indicative of a global acceleration of the carbonate pump during this interval. We suggest that the higher calcite production during the Termination II may have resulted in an increased carbon sequestration, possibly acting as a negative feedback towards CO_2, contributing partly to the mitigation of the Late Pleistocene global warming.

New constraints on reservoir ages and deglacial climate events in the North Atlantic

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Paleoclimate records from the North Atlantic show some of the most iconic signals of abrupt climate change during the ice ages, but variable reservoir ages and regionally distinct paleoclimate signals complicate chronologies. Here we present a stack of North Atlantic surface radiocarbon reservoir ages over the past 40,000 years, using new synchronized age models from over 25 sediment cores refined with thorium normalization between tie-points. This stack shows consistent and large changes in reservoir age, with rise from the last glacial period into the LGM, climb further into early HS1, and then drop abruptly prior to the onset of the Bolling-Allerod. We use the intermediate complexity earth system model cGENIE to investigate the potential drivers of these reservoir age changes. We find that sea ice, circulation and CO_2 all play important roles in setting the reservoir age. We use these coherently dated records to revisit the sequence and timing of climatic events during HS1 and the last deglaciation, and show that Laurentide Heinrich Events are a response to stadial conditions, rather than their root cause.

Modeling of glaciers in Cerro Chirripó National Park, Costa Rica, during the last glacial-interglacial transition

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Reconstructing past mountain glacial extents in the tropics provides insight into the climatic conditions in a geographic region where the influence of temperature forcings needs better temporal and spatial resolution. Here we focus on simulating past extents of mountain glaciers in the humid inner tropics (~10N-10S latitude), where glacial mass balance is sensitive to temperature. We present simulated glacial extents in Cerro Chirripó National Park in the Cordillera de Talamanca Range of Costa Rica during the Last Glacial Maximum (LGM; ~26-19 ka) and Termination 1 (19-11.7 ka). We aim to reconstruct combinations of temperature, precipitation, and lapse-rate values relative to modern values needed to simulate glaciers to the mapped and dated glacial extents. We are using a two-dimensional numerical model that incorporates surface energy balance and ice-flow models and modern climatic input variables including temperature, precipitation, lapse rate, short-wave radiation and wind speed. We adjust the modern climatic variables to the past based on prior work and other proxy records (e.g., pollen records that provide estimates on precipitation change relative to modern). We will compare the climate conditions determined for the LGM and Termination 1 in Costa Rica with prior reconstructions for the site as well as for other sites including the Rwenzori Mountains of East Africa and mountain ranges in New Guinea to assess climate variability throughout the tropics during the last glacial-interglacial transition.

Variations of marine primary productivity in the southeastern Arabian sea during the last two glacial terminations

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Carbon dioxide outgassing during the glacial terminations is one of the main mechanisms for onsets to pull earth out from its cold periods. Marine primary productivity holds large of this CO_2 Outgassing where marine phytoplankton accounts for nearly half of global net primary production. As they die and sink, the organic matter gets preserved in the ocean bottom and gets cut out from the global carbon cycle. This sequestering of atmospheric CO_2 plays a crucial role as a feedback system in glacial-interglacial cycles. Tropical Oceans witness both open ocean and coastal upwelling-induced primary productivity. Here, we present a new paleo-proxy dataset from the tropical Indian Ocean to demonstrate how the primary production has changed during these tipping events. The tropical southeastern Arabian Sea experiences intense upwelling during the Indian summer monsoon season triggering the phytoplankton bloom and is an ideal region to observe these changes. We made use of a marine sedimentary core SSD004 GC11 collected at a depth of 2901m, in total 584 samples covering the span of last 175 kyrs were analyzed for the $\delta^{13}C_{org}$ and Total Organic Carbon (TOC) to reconstruct the variation in primary productivity. We report severe decrease in marine primary productivity during the glacial termination events. The plausible reasons for the decline in primary production include rapid rise in sea level and weakening of AMOC, both triggered by the melting of continental ice sheets. We suggest that the low primary production in the tropical Indian Ocean has assisted in the rapid global CO_2 rise, which worked as positive feedback along with insolation during termination I and II.

Multi-model assessment of the climatic evolution of the last deglaciation at high southern latitudes

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The quaternary climate is characterized by glacial-interglacial cycles, with the most recent transition from the last glacial maximum to the present interglacial (the last deglaciation) occurring between ~ 21 and 9 ka. Paleo-proxy records from high southern latitudes suggest that the deglacial warming was not constant, as indicated by the onset of warming, rapid warming, or response to AMOC due to the bipolar seesaw mechanism. A few transient simulations of the last deglaciation have been used to examine the processes leading to the deglacial high southern latitude temperature evolution. To enhance our understanding of deglacial processes, the 4th phase of the Paleoclimate Modelling Intercomparison Project (PMIP4) working group proposed a common framework to perform transient simulations of the last deglaciation.

In this study, we analyze results from six climate models that have carried out transient simulations of the last deglaciation under the PMIP4 protocol. We analyze 21 to 11 ka focusing on climatic changes in the high southern latitudes and their inter-model differences. We find that one model exhibits a significant annual mean warming trend between 21 and 18 ka (1 degree / 3000 years) without significant AMOC change. Some other models exhibit similar warming trends during that time period, which could be due to a bipolar seesaw response to the AMOC reduction. The subsequent period (18 to 15 ka) shows significant warming related to increased atmospheric greenhouse gases and an AMOC weakening in some models. The subsequent cooling (15 to 13 ka) occurs in some models with an abrupt increase in the AMOC, while the models that simulate an AMOC shutdown at that time simulate a high southern latitude temperature increase. We note that the different time evolution of AMOC changes arises from the different approaches used to estimate glacial meltwater input in the Northern Hemisphere. Overall, we find that the deglacial increase in atmospheric CO_2 concentration and the AMOC weakening are the main controls on surface air and ocean temperature during the deglaciation.

Phase relationships between paleoclimate records during glacial inception and termination periods

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To understand climate changes and associated driving forcing (insolation, CO_2 concentrations, and ice sheets) for glacial inceptions and terminations, we investigated the timing of changes in multiple proxy records including seasonal and annual mean sea surface temperatures (SSTs) and benthic foraminiferal $\delta^{18}O$ that were reconstructed from the same materials of IODP Site U1429 in the northwestern Pacific margin. Investigation of multiple proxy records in a single core can be an advantageous approach to achieve this research goal. Regarding U1429 SST records, we used high-resolution records of alkenone-based annual mean and *Globigerinoides ruber* Mg/Ca-based summer SSTs over the past four interglacial-glacial cycles (~400 kyrs). Our proxy records have an average resolution of approximately 100 years for the inception and glacial periods. According to our records, despite being SST proxies, different proxies present different temperature variations in the same core materials. Phase relationships between the proxy records and climate forcing demonstrate that the temperature variations were associated with different climate forcing. Our records reveal that, during the glacial termination period, the CO_2 concentration began to increase first, and annual mean SST increased simultaneously responding to CO_2 changes. After then, summer insolation increased, and in response to this, summer SST increased during the late termination period. Followed this change, U1429 benthic foraminiferal oxygen isotopic ratios decreased, indicating a decrease in ice sheet volume. During the glacial inception period, summer SST changes initiated to decrease first by responding to summer insolation decrease. By following this, benthic foraminiferal $\delta^{18}O$ increased, indicating the initiation of building of ice sheets. After then, CO_2 and annual mean SSTs decreased during the late glacial inception period.

How coupled were the benthic and planktic oceanic environments off Oman, over the last Glacial-Interglacial Cycle?

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The Oman margin plays a vital role in bringing monsoon to India and thus has been of interest to many climatologists as well as palaeoclimatologists worldwide. From the work done so far it is clear that most of the work along the Oman Margin either covers long durations, low resolution palaeoclimatic data or are focused on understanding monsoon dynamics, upwelling, productivity and SST in the region using planktonic foraminifera. No significant attempts have been made to understand the hydrographic changes in the area and its impact of the benthic environment or its connections with the Eastern Arabian Sea (EAS). A few attempts with benthic foraminifera have been able to detect the Oxygen Minimum Zone and its relationship with productivity. However, benthic assemblages have not been described and no attempts have been made to understand changes in the environment of deposition. There are a few stable isotopic studies done to understand the hydrodynamics and the influence of Persian Gulf waters and the Red Sea waters on the study area. No work has been carried out using comparative studies of benthic and planktic foraminiferal assemblage and / or coupled benthic-planktic isotopic signatures.

The present study presents high resolution multi proxy records on a sediment core collected on the upper slope of the Oman Margin. It is the first multiproxy approach to decode the benthic and planktic hydrography in the region over the last glacial-interglacial cycle. Sediment textures, benthic foraminiferal assemblages, planktic and benthic oxygen and carbon isotopic signatures provide crucial insights into how the benthic ocean responded to the warming of the surface ocean when the glacial ice-sheets started melting during the Late Glacial Warming and the Holocene Sea Level rise.

Key words: Foraminifera, Stable isotopes, benthic assemblages, Oman margin, coupled responses

Modeling the retreat of the North American ice sheet

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Due to the current rise in global temperatures the Antarctic and Greenland ice sheets are at risk to melt in the future. Ice sheets have fully melted in the past. Large parts of Eurasia and North America were covered by ice 21 thousand years ago, which have since fully melted. Understanding the mechanisms that lead to this deglaciation may help us to understand what will happen to Antarctica and Greenland in the future.
Mass loss of ice sheets can be attributed to three processes: surface melt, basal melt and calving. During the deglaciation of the North American ice sheet, a proglacial lake was formed at the southern margin allowing for ice-water interactions. In this study we simulate the deglaciation of the Northern Hemisphere ice sheets using an ice-sheet model to investigate which mechanisms are responsible for deglaciation.
We found that by excluding either or both calving and basal melt North America can still deglaciate fully by present day, suggesting that solely surface melt is sufficient for melting the ice sheet. At the southern margin of the North American ice sheet a proglacial lake allows for floating ice. Floating ice has negligible basal friction and therefore has increased ice velocities compared to grounded ice. This decreases ice thickness and surface topography, and increases surface temperature. As a result, this floating ice has high melt rates and accelerates the deglaciation of the North American ice sheet. By applying the basal friction of land to floating ice, the North American ice sheet retains an ice volume of 13.3 meters of sea level equivalent by present day.

Hydrological variability in the Agulhas current across Terminations I and II as inferred from geochemical multi-foraminiferal species in the Mozambique Channel: link with transient simulations

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The Mozambique Channel is an important region for ocean circulation, as it is the source of the Agulhas Current, which contributes to the Agulhas leakage. The Agulhas leakage acts as a climate modulator by transferring warm, salty waters to the Atlantic and thus contributing to the efficiency of the thermohaline circulation. This work investigates the hydrological variability of the Agulhas current (spatial and temporal) at different depths in the water column of the Mozambique Channel during Terminations I and II. A multi-proxy approach (O and C stable isotopes, Mg/Ca paleothermometer, foraminiferal U/Ca, and planktic foraminiferal assemblages) is applied to two cores in order to reconstruct a latitudinal gradient and characterise the water column structure from the surface to the ocean floor. Several foraminiferal (planktic and benthic) species were selected according to calcification depths: *G. ruber s.s*, *N. dutertrei* for surface and subsurface waters and *C. wuellerstorfi* for deep waters. The main results indicate a decoupling between surface and subsurface waters, which suggests an earlier warming for subsurface waters associated with an increase in salinity during both Terminations. On the other hand, bottom waters show a decrease in ventilation synchronous with the slowing down of the thermohaline circulation at the beginning of Terminations. These results will be discussed in the light of the latitudinal migration of the subtropical front during TI and TII and the related intensity/effectiveness of the "Agulhas leakage" and transient simulations performed with Earth system models.

Proposal IODP 985-Full2: Eastern Fram Strait Paleoarchive (FRAME): Science and research opportunities during and after Exp-403 (June-August 2024)

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The research proposal IODP 985-Full was motivated by the necessity of retrieving continuous, high-resolution, and datable depositional sequences containing the record of the palaeoceanographic characteristics and cryosphere evolution during the past key climatic transitions that followed the opening of the Fram Strait in the Arctic. Such data are greatly needed to better constrain global climate connections, forcing mechanisms and climate models.

High-resolution, continuous depositional archives were identified in the contourite drifts (Bellsund, Isfjorden, Svyatogor and Vestnesa) developed on the mid-upper slope of the western continental margin of Svalbard (eastern Fram Strait) under the effect of the West Spitsbergen Current (WSC) transporting sediments and warm Atlantic Waters to the Arctic Ocean, exerting a strong control on climate variability.

The general objective of FRAME is the reconstruction of the variability of the WSC and its influence on climate changes particularly during key Quaternary climate transitions and beyond (the late Miocene–Pliocene transition, late Pliocene–Pleistocene Transition, Mid-Pleistocene Transition, Mid-Brunhes Transition, and sub-orbital Heinrich-like events), its impact on the Arctic glaciations, ice shelves development and stability, and sea ice distribution over last 5.3 Ma.

The proposal was submitted in April 2020 as outcome of the Magellan+ Workshop EFRAM-ARC, held in Trieste (Italy) in January 2020. IODP 985-Full was approved in May 2022 and scheduled as IODP Exp. 403 of the JOIDES Resolution that will take place from June 4th to August 2nd, 2024 (http://iodp.tamu.edu/scienceops/expeditions/eastern_fram_strait_paleo_archive.html). Scientists and PhD students can take part in FRAME research by applying to become shipboard scientist or by submitting sample requests after a moratorium period of one year.

The Holocene marine benthic ostracod record of the Alkyonides Gulf (Corinth Basin, Greece) in a Mediterranean perspective

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The Gulf of Corinth is a narrow arm of the Mediterranean, currently connected to the Ionian Sea and the wider Mediterranean Sea by the Rion Sill and Acheloos-Cape Pappas Sill in the west (at 60 m and 55 m below sea level, respectively). In the east, the artificial 22m-wide, 8 m-deep Corinth Canal connects the Gulf with the Aegean Sea. The aim of IODP Expedition 381 was to sample sediments deposited in the Corinth Basin formed during the earliest stage of continental rifting. Details of the Corinth Basin's environmental change from glacial to interglacial states are poorly known. For example, the precise timing of transition from lacustrine to marine conditions is unconfirmed in addition to the interacting controls of basin subsidence, sill elevation and eustatic sea level. Benthic ostracods (microcrustaceans) inhabit virtually all aquatic environments on Earth, and they are the only micropaleontological proxy that can live in all the paleo-environments that this study spans. As such they provide a unique and continuous record of paleoenvironmental evolution of the area. Previous studies on core M0080 revealed that when the Mediterranean Sea level dropped below the sill height and separated the Gulf of Corinth from the Mediterranean, major faunal transitions occurred from lacustrine (Ponto-Caspian, Lake Corinth) glacial-age assemblages to fully marine (Mediterranean) during the last 20 kyr. During deglacial periods, the Corinth Gulf [GL1] [CTM2] was characterized by fully marine conditions, and Mediterranean waters breached the shallow sills. A detailed study of the benthic ostracod assemblages from two cores, M0080 and M0078, provides useful insights about the timing and evolution of the salination of the water body as well as suggests water mixings due to hyperpycnal flows down from the sill.

Glacial-interglacial ice-rafted debris variability in the western Indian sector of the Southern Ocean: Palaeoceanographic implications

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Little is known about the ice-rafted debris (IRD) inputs to the Indian sector of the Southern Ocean (ISO) during the middle to late Pleistocene. In this study, we present first combined data of morphological and geochemical investigations on IRD grains obtained from sediment core MD19-3576, collected from Del Caño Rise in the ISO during MD218 CROTALE cruise. The sediment core chronology was developed by tuning its blue reflectance with the benthic stable oxygen isotope record (LR04). Our data show a higher fractional abundance of biogenic fragments and lesser IRD in the coarse fraction (>250 µm) of sediments during the major glacial-Interglacial transitions (Terminations V, IV, III, and II) and during the interglacial periods. On the other hand, glacial periods are characterised by lesser biogenic fragments and higher IRD concentrations (<15 and up to 35 %). High blue reflectance along with the higher fractional abundance of biogenic fragments, whereas negligible IRD concentration during the interglacial periods and major terminations indicate that the warmth significantly reduced ice capping and possibly provided favourable conditions for marine productivity bloom in the ISO. The IRD principally consist of quartz, volcanogenic lithic fragments and crystalline rock fragments. The presence of volcanogenic lithic fragments (300 to 500 µm) within the IRD bearing sections of the core reiterates Sub-Antarctic origin of IRD. Additionally, the SiO_2 and Na_2O+K_2O percentages of the volcanic and crystalline grains agree well with the geochemical characteristics of rocks from the nearby volcanic islands, e.g., the South Sandwich and Marion Islands. On the other hand, the presence of garnet and quartz bearing lithic grains within IRD flux especially during the Terminations V and IV suggest that Antarctic ice mass loss might be a possible factor that contributed to the IRD flux to the core site. Therefore, it indicates a northern boundary of Antarctic iceberg variability during the Pleistocene glaciation in the ISO. Our study opens up a new possibility to investigate long term variability of Antarctic continental ice sheet stability as well as sub-Antarctic IRD variability, which will provide vital information to reconstruct iceberg trajectories and the northern extent of iceberg transport during Pleistocene glaciation.

Were Patagonian glaciers smaller than today during past extreme warm periods?

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Present-day warming is triggering a *global-scale glacier crisis*. Glaciers worldwide have undergone rapid melting, at rates that have surpassed our most extreme predictions and that have never been recorded before in the instrumental or geologic record. Global changes in mountain glaciers are causing dramatic impacts on both physical (e.g., landslides, flooding) and ecological systems (e.g., ecosystem shifts). The livelihoods of hundreds of millions of people downstream from melting glaciers is under threat. Unfortunately, due the nature of the geologic record, most of our understanding of past glacier-climate interaction comes from the study of cold periods. Thus, predictions as to possible glacier changes in the near-future and their potential impact are hampered by limited knowledge on prior glacial response during warm periods. This is particularly relevant for the extra tropical Andes, a region that contains the two largest icefields in the Southern Hemisphere, which exhibit some of the highest melting rates on the planet. Here, we explore the response of Patagonian glaciers to past, extreme warm conditions. We will combine surface measurements of multiple cosmogenic nuclides (^{10}Be, *in situ* ^{14}C and ^{36}Cl) to quantify the cumulative duration of periods when selected Patagonian glaciers were smaller than today during the last 450,000 years of Earth's history. This information is crucial to understand whether the magnitude of present-day deglaciation is unique and unprecedented within the recent geologic history, and to put the response of glaciers to present-day climate change into context. The application of this cutting-edge cosmogenic nuclide technique ushers in a new era of glacier-climate science, allowing for the systematic investigation of glacier behavior during warm periods.

Solving the paradox of conflicting glacial chronologies: reconstructing the Cordillera Darwin ice sheet (53°-55°S) during the last glacial – interglacial transition.

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During ice ages, cooler climate coupled with high precipitation fed by the southern westerly winds and orographic processes caused the Patagonian ice fields to expand and glaciers to flow to the edge of the continental shelf in the west and through the major valleys and ice-scoured troughs in the east. Successive glacier advances have left a suite of glacial landforms and glacial deposits, including glacial lacustrine sediments from ice dammed lakes, that allows us to reconstruct the extent and timing of former glacier fluctuations. However, the evidence we have at present from southern Patagonia and the Cordillera Darwin (54°S) is contradictory. There is evidence (glacial lacustrine sediments, raised shorelines) for the formation of large (approx. 9,000 km^2) pro-glacial lake in the Strait of Magellan (estrecho de Magallanes) between c. 15.0 and 12.0 cal yr BP; broadly coeval with the Antarctic Cold Reversal. This necessitates a more extended ice cap damming meltwater routes to the Southern Ocean during the Late glacial. However, there are cosmogenic and ^{14}C ages from the north-eastern margins of the Cordillera Darwin for earlier (> c.16.0 cal yr BP) glacier retreat which suggests a smaller Late glacial ice cap that appears less likely to have supported a large Magellan pro-glacial lake. Here we present new cosmogenic, ^{14}C and OSL ages, supported by tephrochronology, from the southern Strait of Magellan and the Cordillera Darwin. These new ages help constrain the timing of glacier retreat from the southern Strait of Magellan and into the fjords and channels around the western flanks of the Cordillera Darwin. We suggest that significant westerly ice divide migration (i.e. towards the source of precipitation) of the Cordillera Darwin ice cap would have enabled the persistence of ice dams supporting the Magellan pro-glacial lakes, while being consistent with earlier deglaciation to the north and east of the ice cap.

Reconstructing glacier change between 31°S and 40°S in the Chilean Andes since the Last Glacial Maximum

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Local geochronological studies in the Chilean Andes suggest that glaciers were sensitive to changes in temperature and precipitation during the Last Glacial Maximum (LGM) and Holocene. Glacial histories are latitudinally asynchronous and the timing of glacial maxima vary sub-regionally. Whilst extensive glacial geomorphological mapping has been completed across much of the Chilean Andes, there is a large gap in the Southern Andes between 31°S and 40°S where the timing and pattern of glacier change has not been constrained.
Here, we present a synthesis of existing literature and a compilation of moraine geochronological data representative of glacier change between 31°S and 40°S. We also present the results of geomorphological mapping to determine ice marginal extents during and since the last glaciation, to enable interpretations of palaeo-glacial behaviour and dynamics. This analysis was based on high-resolution PlanetLab and Google Earth satellite imagery to remotely map terminal and lateral moraines following standard identification criteria. In addition, we plan to sample boulders from moraines in the Olivares Basin in the Maipo Valley, ~52 km northeast of Santiago, for cosmogenic nuclide exposure-age dating to produce a geochronology for this valley. These results will be used to produce a comprehensive reconstruction of glacier change in the semi-arid Andes since the LGM and through the Holocene to understand the timing of maximum glacier extent in a largely understudied and unconstrained region of the Chilean Andes.

Post-Glacial dynamics of the Patagonian Ice Sheet across the Southern Volcanic Zone

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During the Last Glacial Maximum (LGM), the Patagonian Ice Sheet (PIS) formed a contiguous cap over the southern Andes from 38° to 55° S, with an ice mass loss that accounts for 1.2 m of post-glacial sea level equivalent. While glaciological observations and remotely-sensed data allowed for a comprehensive understanding of glacier mass changes during the last century, detailed deglacial reconstructions of the PIS are needed for contextualizing such changes. Despite recent progress in investigating regional post-glacial ice sheet configurations, constraints on the climatic drivers of the last glacial to interglacial transition remain elusive in the Southern Volcanic Zone, and present a possibility to evaluate ice sheet sensitivity to such forcings. In order to precisely determine the timing and rate of ice sheet retreat, as well as to account for volumetric changes, we employ cosmogenic nuclide surface exposure dating with 10Be from exposed bedrock surfaces at elevations ranging from 1000-3000 meters across the Southern Volcanic Zone. Using these data as constraints, we then perform transient simulations of the PIS during the last deglaciation with the Ice Sheet and Sea-level System Model (ISSM) to test the sensitivity of the northern PIS to changing climatological inputs driven by the Community Climate System Model (CCSM3) Trace-21ka experiment. Our new data and model simulations provide a comprehensive data-model comparison to investigate both the timing and drivers of post-glacial ice sheet change following the last glacial period.

Revisiting the history of the Río Cisnes Glacier, Patagonian Ice Sheet (44°S) - new insights from luminescence and surface exposure dating

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The glacial geomorphology of Patagonia comprises one of the most complete records of glacier fluctuations during the Quaternary. Recent progress in mapping, interpretation and dating enabled the reconstruction of the last glaciation and deglaciation, providing insight into paleoclimatic and paleoenvironmental conditions of the region. In the Cisnes river valley in the Aysén region, Chile, a complex geomorphological and sedimentological record of the last glacial cycle has been preserved, including moraines, glaciolacustrine and glaciofluvial sediments, allowing for the reconstruction of the LGM ice extent, the retreat of the ice front during termination 1, the formation of proglacial lakes and the subsequent reversal of the general flow direction to today's conditions with Río Cisnes draining the valley westward towards the Pacific.
Results of Garcia et al. (2019) provided a first robust chronological and geomorphological framework especially for the process dynamics in the Late Glacial, however, new questions were raised with respect to the timing of the maximum ice extent during the last glacial cycle and the process dynamics throughout the Late Glacial and into the Holocene. Here we present new results from luminescence dating (using a pIRIR225 (post infrared, infrared stimulated luminescence @225°C) protocol for single grains of potassium-rich feldspar), surface exposure dating using cosmogenic nuclides (^{10}Be and ^{36}Cl), and radiocarbon dating to refine the geochronological record especially for the LGM and the Late Glacial to Holocene times. The new age constraints allow insights into the LGM ice dynamics and the paleoenvironmental development during the Late Glacial to a phase of prevailing fluvial erosion in Holocene times. The results have paleoclimatic and paleogeographical implications, thus helping to understand glaciation and deglaciation in Patagonia, its chronology and associated geomorphological processes. Our results show that the glacial maximum of the Cisnes lobe occurred during the global LGM, whereas advances during MIS 4 or MIS 3 as observed in other areas of the Patagonian Andes are lacking. The deglaciation period was characterized by erosional processes and incision of previously deposited glacial sediments, with the Cisnes River forming fluvial terrace systems starting during the Late Glacial to Holocene transition phase and lasting well into the Holocene.

A 3He based Holocene glacial chronology from Villarrica volcano, Chile

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Understanding how glaciers have changed in the past lends important information about prior climate variations and provides insight on the glacial driving mechanisms on decadal to millennial timescales. In turn, understanding past glacial conditions provides insight into how the cryosphere might respond to future climate change. Here we address the timing of Holocene glaciation at Villarrica volcano (39°S) – a composite volcano located in the Southern Volcanic Zone (SVZ) of central Chile that was encased by the Patagonian Ice Sheet during the Last Glacial Maximum (LGM) and continues to support glaciers today. Moraines along the flanks of the volcano demarcate past glacial positions during the latest Pleistocene to Holocene when ice extent was greater than today. The eruptive products of Villarrica are composed of olivine rich basalts to basaltic-andesites presenting an ideal opportunity to perform cosmogenic surface exposure dating with ^{3}He on moraine boulders. To date, the post-LGM glacial history of the SVZ is poorly constrained, limiting our understanding of how glaciers in the Southern Hemisphere behaved during the last deglaciation and Holocene when climate conditions were drastically changing.

To characterize Holocene glacial extent in the SVZ, we collected ~25 samples for surface exposure dating with ^{3}He from boulders obtained along the crests of several moraines at Villarrica volcano. Initial results from moraine boulders from a right lateral moraine deposited by Pichillancahue-Turbio glacier on the eastern flank of Villarrica indicate moraine abandonment between 500-1,000 years b.p. (n= 3). We will present additional ^{3}He ages from several other moraines deposited by Pichillancahue-Turbio and Voipir glaciers to fill spatial gaps and complete the glacial chronology around Villarrica volcano. Our new Holocene glacier chronologies will provide improved constraints of ice retreat in this sector of the SVZ and fill critical gaps in chronologic control on recent glacial changes in northern Patagonia.

The Eltanin 27-21 magnetic record of deep sea sediments in the Ross Sea area over the last 2.2 Myrs

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The Eltanin 27-21 magnetic record of deep sea sediments in the Ross Sea area over the last 2.2 Myrs

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ABSTRACT:

The Eltanin 27-21 Core provides a unique opportunity to study environmental magnetic variability in a continuous Pleistocene deep-sea sedimentary record, retrieved from the lower continental slope in front of Ross Sea, Antarctica (Cape Adare). The high-resolution magnetostratigraphy of the Eltanin 27-21 Core demonstrates the cyclical nature of the environmental magnetic record, directly linked to orbital periodicities of short-term eccentricity (100-kyr) and obliquity (41-kyr) over the last 2.2 Myrs. Magnetic minerals concentrations influenced by terrestrially derived materials driven by glacier dynamics and biological material related to blooms during the early interglacials, are related to Ice Rafted Debris and, consequently, Ross Sea Ice Sheet (RSIS) dynamic. Eltanin 27-21 magnetic mineral concentration testify advances and retreats of the grounding line of the RSIS, which are linked to global climate change. Magnetic minerals concentrations show same amplitude fluctuations during maximum extensions in the '41-kyr world' and in the '100-kyr world' also if glacials were shorter and sea-level drop was smaller (35 and 65 m) before the Mid Pleistocene Transition (MPT) and was larger (75 and 115 m) after the MPT, providing a new perspective on climate sensitivity.

Application of novel methods of estimating relative pollen productivity: a key for reconstruction of past land cover from pollen records from Patagonia

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Pollen analysis has been the principal tool to reconstruct past vegetation patterns to understand plant dynamics and the response to natural and anthropogenic disturbances. Most palynological studies emphasize the role of climate in driving vegetation patterns. In Patagonia, many studies have focused on glacial and postglacial vegetation changes and shifts in the position and strength of the southern westerlies. However, the interpretation of the palaeo record depends on understanding the relationship between pollen production and dispersal and the land cover at the time, which is poorly understood. The evaluation of quantitative methods in vegetation reconstructions at a local scale is needed to improve the reconstruction of past vegetation cover in Patagonia. Models such as REVEAL and LOVE have been applied in the northern hemisphere resulting in more accurate estimates of the regional/local vegetation by incorporating parameters such as pollen productivity, pollen dispersal, basin size, and background pollen input. To apply the REVEAL and LOVE models, the first step is to estimate the relative pollen productivity (RPPs) for relevant plant taxa, a key input parameter for regional and local vegetation estimates. In this study, we aim to obtain quantitative estimates of pollen productivity for different vegetation types in the Aysén region (43°-49°S) and apply them to reconstruct vegetation cover of past landscapes to inform conservation strategies. Initial results show that the plant diversity recorded in the area around a pollen sample is not reflected in the pollen assemblage. Moreover, introduced taxa such as *Pinus* sp, the most abundant alien species in the region, override most of the local vegetation signal. Within open *Nothofagus* forest, dense understory of shrubs species (e.g. *Gaultheria*) represent <1% on modern pollen samples. Given these results, paleo pollen records do not closely represent actual plant diversity. Therefore, the calibration and testing of landcover reconstruction models is key to effectively reconstruct quaternary landcover from pollen records in this region.

Late Holocene riparian vegetation dynamics, environmental changes, and anthropogenic impact in the Harapan forest of Sumatra, Indonesia

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Wetlands are important ecosystems for carbon sink but are vulnerable due to climate change and human activities. For the past few decades, wetlands in Sumatra are under transformed and converted into arable lands. Aiming to understand the effects of natural factors (e.g. climate change, flooding, drought) and human activities (e.g. agriculture, socioeconomically local communities) on wetlands is vital for development of management strategies. For that, we conducted a multi-proxy palaeoecological analysis, including pollen and spore, macro-charcoal and radiocarbon dating, on a sediment core taken at a riparian area in the Harapan forest, Sumatra. The results show an ecosystem evolution from riparian forest to freshwater swamp during the last 1000 years. Three periods are highlighted: i) AD 1100 - 1400: the sandy layers associated with the frequent pollen of riparian and swamp vegetation (e.g. *Calamus*, *Elaeocarpus, Pandanus*, Dipterocarpaceae, *Mallotus/Macaranga*, Poaceae) indicate the presence of freshwater swamps of *Pandanus, Elaeocarpus*, grasses and herbaceous mashes nearby the study site, that was possibly abandoned channels or oxbow lake; ii) AD 1400 – 1820: a high frequency of swamp vegetation (e.g. *Calamus, Tristaniopsis*, Dipterocarpaceae) suggests that the freshwater swamps started either expanding to the study site or the study site itself evolved into freshwater swamps after being cut off from the river; iii) later, from AD 1820 to present, this ecosystem became a closed canopy of freshwater swamp mixed lowland forest with the dominant Dipterocarpaceae, Icacinaceae, *Elaeocarpus, Lithocarpus/Castanopsis*. The presence of oil palm (*Elaeis guineensis*) at the end of this period indicates the presence of small-scale agriculture in the Harapan catchments. For the first time, the detail of riparian vegetation dynamics and environmental changes in the Harapan forest of Sumatra has been studied, showing the evolution of the freshwater swamp under the impact of climate change and human activities. The insight of this study allows us to predict and explore the response of wetland vegetation in Sumatra to climate change and human impacts in the future.

Investigating and refining the use of oxygen isotopes from chironomid head capsule chitin to reconstruct past climatic changes

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Oxygen-isotope records derived from authigenic lacustrine carbonate allow for detailed quantitative reconstructions of past climate change and have been vital in improving our understanding of LGIT climate dynamics. However, their application is restricted to carbonate lakes. Even for lake which do contain carbonate-rich sediments, there are several limitations including: (i) carbonate precipitation is subject to temperature fractionation effects during formation; (ii) detrital allogenic material can contaminate the isotopic signal; and (iii) carbonate precipitation may not be continuous through the sequence leading to discontinuous isotope records. Chironomid head capsules are available in high concentrations in most lakes around the world, even non-carbonate lakes, and analysis of their oxygen isotope composition can overcome some of these issues. Laboratory studies have demonstrated that the isotopic composition of ambient lake water has a strong influence on the $\delta^{18}O$ of the larval head capsule chitin. However, the application of $\delta^{18}O_{chitin}$ for climate reconstruction is still in its infancy, with many aspects still to be explored. Due to the technical capabilities of the time, previous $\delta^{18}O_{chitin}$ studies required large samples (>50 μg) to determine past climate variations. As a result, the analysed samples contained multiple chironomid morphotypes which may fractionate isotopes differently. The latest GCIRMS-elemental analysers now allow the measurement of much smaller sample sizes, potentially circumventing the issue of having to measure multiple taxa as part of a single sample. Here, we first explore the minimum number of head capsules needed to produce a coherent isotopic signal from a sample using Thermo-Finnigan IsoLink EA. Preliminary results suggest samples as small as 25 μg can be measured robustly. Secondly, we investigate whether different chironomid genera fractionate oxygen isotopes differently. Eleven different morphotypes were analysed for isotopic off-sets from the Lateglacial sediment record of Crudale Meadow. Our results show that isotopic differences as large as 2.5 ‰ are apparent between different chironomid morphotypes, which is of similar or even greater magnitude than the isotope shifts between the Lateglacial Interstadial (GI-1) and the Loch Lomond Stadial (GS-1).

Lateglacial vegetation dynamics of the central Pyrenees: the Bassa Nera record

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The ecological dynamics of mountain vegetation from the Pyrenees as a response to Late Glacial environmental dynamics is poorly known due to the paucity of past records encompassing this time interval. This work uses palynology to reconstruct the development of high-mountain ecosystems as a response to climatic changes that occurred between 15 and 10 cal ka BP, at multidecadal resolution, which is unprecedented in the few available studies. Paleoclimatic and paleoenvironmental trends are deduced from independent physicochemical records developed on the same sediments, along with detailed studies on glacial deposits and landforms, which are available for the study area during the period of interest. The sediments of the Bassa Nera pond are especially well suited for this type of analysis because its elevation, slightly below the present treeline, makes the site highly sensitive to altitudinal oscillations of montane vegetation belts. Emphasis is placed on treeline altitudinal shifts during the Bølling/Allerød-Younger Dryas interstadial/stadial succession, and the existence of potential microrefugia for high-elevation conifer forests. Another point of interest is the analysis of community versus individual species' response to environmental change, aimed at identifying the most suitable indicator taxa. In the study area, the Late Glacial time interval was free from human disturbance and is therefore an excellent past analog to assess the effect of climatic shifts alone on high-mountain Pyrenean ecosystems. The results obtained in this study are placed within the context of the conspicuous spatiotemporal anthropization gradient that has been defined for the central Pyrenees, which will be useful to disentangle the effects of natural and anthropogenic drivers of ecological change. The Bassa Nera pond is located in a National Park (PNAESM) and the results obtained in this study will be useful to inform conservation practices in the face of the ongoing climatic change. Research funded by project LACEN OAPN 24505 (Sentinel Lakes of Global Change in National Parks).

Disentangling the influence of climate and lake-basin evolution on GDGT-based proxies: the 250-ka Lake Chala record

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High-resolution paleoclimate records from equatorial continental settings are needed to deepen the current understanding of global climate dynamics. Biomarker studies on the sediment archives from long-lived lakes can provide records of past climate variability from such underrepresented regions. However, the degree to which biomarker proxies are impacted by aspects of long-term lake-basin development is rarely discussed, even though it may critically influence their ability to consistently reflect a particular climate variable through time. The International Continental Scientific Drilling Program (ICDP) project DeepCHALLA recovered a continuous sequence of diatom and organic-rich sediments from Lake Chala, a permanently stratified crater lake in equatorial East Africa, spanning the last c. 250,000 years (250 kyr) likely reaching the initial lake infilling. A series of modern system studies in Lake Chala have revealed crucial information about the mechanisms unpinning biomarker proxy-climate relationships, but the permanence of these relationships in deep time remains unclear. To assess the reliability of the climate signal recorded by isoprenoid (iso-) and branched (br-) glycerol dialkyl glycerol tetraethers (GDGTs) in these sediments, we compared downcore variations in GDGT distributions at ~200 year resolution with major phases in basin evolution, mixing regime, and nutrient dynamics as indicated by independent proxies (seismic reflection data, lithology and diatom assemblages). Together, these records suggest that during the early phases of the lake's development the clearly defined mixing zones to which specific GDGT producers are presently associated were not yet established, due to the lack water column stratification. As a consequence, before ~150 ka many of the GDGT-based proxies show irregular trends, and periodicities reflecting expected orbital insolation forcing of the local climate are mostly absent. Therefore, we conclude that GDGT proxies in Lake Chala primarily reflect climatic changes in equatorial East Africa from ~150 ka onwards, i.e., covering the complete last glacial-interglacial cycle. This work demonstrates the potential of lacustrine GDGTs for elucidating tropical climate history at Quaternary timescales provided the availability of suitable high-quality sediment archives, and, furthermore, sets a new standard for lacustrine biomarker studies to incorporate a broader understanding of lake basin evolution or else risk misclassifying past climate conditions.

Untangling climate-driven changes in pollen signals from external drivers; a study of pollen in deep marine deposits on the active Hikurangi Subduction Margin, New Zealand.

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Pollen is a valuable and reputable tool for reconstructing paleoclimate and is often preserved within marine sedimentary records, capturing the onshore vegetation response to changing climate states. A benefit of using marine sedimentary records for reconstructions is that they span longer timeframes than are typically available from terrestrial sites. However, reconstructing climate and vegetation from marine records can often be more complicated than reconstructions from terrestrial records. Furthermore, active sedimentary systems adjacent to tectonically active margins pose additional challenges, as the sedimentary sequence can be heavily influenced by extreme events, including volcanic eruptions, earthquakes, and submarine density flows. Therefore, to harness records from these environments for paleovegetation and paleoclimate reconstruction, the distribution of palynomorphs above and within tephra from volcanic eruptions, turbidite event beds from earthquakes, and hyperpycnites from major storms must be understood.

To investigate this relationship, we use the Hikurangi Subduction Margin (HSM) as a case study as it is an active sedimentary margin, influenced by volcanic eruptions from the adjacent Taupō Volcanic Zone, frequent earthquakes and major storms due to New Zealand's maritime climate. We present preliminary results from short sediment cores collected from the HSM, comparing palynomorph assemblages and sedimentary facies from Holocene turbidites, hyperpycnites and primary and secondary tephras. Pollen spectra, CT imaging, magnetic susceptibility measurements, density measurements, laser grain-size analysis and carbonate analysis are used to investigate the relationships between sedimentary facies and palynomorph assemblages. In turbidite and hyperpycnite beds, we hypothesise that results will show evidence of palynomorph sorting according to size, morphology and exine thickness. Within and above tephras deposited in the HSM from major volcanic eruptions, we hypothesise a potential decrease in the overall pollen species diversity and a subsequent increase in pollen from seral species.

The characterisation of pollen profiles that represent extreme events will make it possible to disentangle the external influence of these events on the pollen assemblage from the true paleovegetation and paleoclimate signal. The findings from this preliminary study will facilitate paleovegetation, paleoclimate and extreme event reconstruction for a Late Quaternary (~1.85 Ma) sediment record from the HSM.

Towards an improved understanding of the Late Pleistocene and Early Holocene eco-climatic context of human activities in the Northern Apennines, Italy.

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Two well-dated palaeoenvironmental records from Liguria (Pian del Lago and Rovegno) in the northern Apennines (NW Italy) were used to reconstruct the timing and nature of sedimentary changes and vegetation succession during the upper Late Pleistocene and Early Holocene. The results from Pian del Lago and Rovegno have provided clear signals for multiple abrupt climatic events: Interstadials at *~43,440-41,950* cal. BP, *~37,130-36,650* cal. BP, *~36,050-35,160* cal. BP, *~33,860-32,650 cal.* BP, *~26,880-26,400* cal. BP, *~23,030 to 22,800* cal. BP, *~14,660-12,480* cal. BP (Lateglacial Interstadial); Stadials at *~22,540-19,300* cal. BP, *~19,300-17,480* cal. BP, *~17,480-14,660* cal. BP and *~12,480-11,560* cal. BP (Lateglacial Stadial - 'Younger Dryas' chronozone). The event stratigraphy proposed represents an enhanced version of that proposed by the authors previously and critically it confirms the presence of further stadial events in the northern Apennines during the upper Late Pleistocene. During the Early Holocene, there is no pollen-stratigraphic evidence to support the presence of the ~11,400 cal. BP rapid climate change event, although the changes in vegetation succession at a number of northern Apennine sites indicate possible signatures for the ~9300 cal. BP and ~8200 cal. BP events. The records from Pian del Lago and Rovegno are supported by other terrestrial sequences in Italy, although there are notable spatial and temporal differences in taxa recorded that may reflect latitude, location of glacial refugia and local site-specific characteristics including elevation, aspect and soil development. Importantly, the presence of these climate events suggests that the northern Apennines were probably sensitive to many of the changes recorded in other parts of Europe and the Mediterranean. The data have provided important new information on the climatic and environmental context of human activities in the Italian Maritime Alps and northern Apennines especially at the transition between the Middle to Upper Palaeolithic, and during subsequent socio-economic and cultural developments during the Late Mousterian, Proto-Aurignacian, Aurignacian, Gravettian, Epigravettian, Mesolithic and Early Neolithic.

5500 years of ecosystem change in the Tana River Delta (Kenya) in response to sea-level fluctuation, hydrological dynamics and human impact

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Coastal deltas worldwide are under risk of degradation due to the increasing impacts of sea-level rise and alterations of river hydrology. This double threat also applies to the Tana River Delta in Kenya, which forms a lifeline for local communities almost entirely dependent on its ecosystem services, while also providing very attractive habitat to a wide variety of flora and fauna that make this area a biodiversity hotspot in the Eastern African coastal region. However, past and historical dynamics that have influenced the current status of the Tana River Delta ecosystem are not sufficiently understood to construct a proper baseline to evaluate the uniqueness and magnitude of the delta's current environmental challenges.

In order to gain such understanding of long-term ecosystem dynamics in the Tana River Delta, we developed a multi-proxy paleo-environmental study involving the analysis of sediment cores recovered from floodplain and mangrove forest areas within the delta. We performed a detailed lithological description and geochemical analyses to determine changes in the depositional environment, and analyses of fossil pollen and aquatic invertebrate assemblages to determine past changes in delta vegetation and aquatic habitat features in response to natural and anthropogenic environmental drivers.

Our results indicate that since the mid-Holocene sea-level maximum *ca* 5500 cal yr BP, the central Tana River Delta evolved from a marine ecosystem dominated by mangrove vegetation to the present-day wooded freshwater floodplain, in response to late-Holocene sea-level decline and subsequent changes in river hydrology. The timing of salinity changes, as registered by aquatic invertebrates, differed between various locations in the delta. In addition, we find that sediment composition and delivery to the delta have been impacted by human hydrological alterations at the basin and local scale over the past two centuries. With continued sediment starvation and hydrological alterations under the current trend of rising sea level, we foresee increased sea intrusion and submergence of the Tana River Delta.

Confocal Raman Spectroscopy Montaging: An open sesame to visualize sub-daily growth lines in short-lived marine gastropod shells

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Confocal Raman Spectroscopy (CRS) is a common, powerful, rapid, and non-destructive technique which is well–established in the field of sclerochronology – the study on the accretionary hard parts of animals such as corals and mollusc shells and the temporal context in which they were formed. CRS has predominantly been used in sclerochronology to determine the crystalline structure (e.g. calcite, aragonite) of mollusc shells and corals. However, this research employs CRM to investigate growth patterns of the short-lived marine gastropod shells, *Rochia nilotica* and *Conomurex luhuanus*, collected from the Great Barrier Reef. Our results show that CRS is a powerful and reliable tool, to visualise daily to sub-daily growth patterns in short-lived marine gastropods, often performing better than other commonly utilised techniques including light microscopy on stained and un-stained sections, and cathodoluminescence (CL). This technique can therefore be used to better understand daily to sub-daily growth patterns in marine gastropod shells and their relationship to tidal cycles, and as a primer for high-resolution biogeochemical analyses of modern and archeological gastropod shells to better characterize the temporal resolution of sampling when obtaining paleoenvironmental records of climate modes such as ENSO at ultra-high resolution.

Integrating palaeoecological and dendrochronological data to explore the past impact of climate and land-use changes on Sphagnum peatlands in the temperate climate of Central and Eastern Europe

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Understanding climate change's extent, rate and effects is one of modern science's most critical challenges. These changes, manifested by increasingly higher average air temperatures and changes in precipitation, are affecting ecosystems globally. *Pinus* sylvestris monocultures, because of their homogeneous structure and simplified ecosystem structure, are particularly vulnerable to extreme events, including insect outbreaks, drought, fire and strong wind. As air temperatures rise and precipitation patterns change, the risk of fires in forests increases. In the context of global warming, forest fires are hazardous. The situation is even more dangerous when, along with a forest fire, a fire occurs in a peatland located in its area. Peatlands are effectively store carbon accumulated over hundreds or thousands of years. The main objective of this study is to reconstruct the history of peatland development over the past 300 years. We chose the Okoniny peatland in the Tuchola Pinewoods (N Poland). We looked at the period associated with the transition from mixed forest/open area to pine monoculture. We also studied the past impact of the change in forest management on the local vegetation and peatland hydrology. In addition, we wanted to answer the question of how the peatland ecosystem responded to extreme events, including natural and anthropogenic fires. Our reconstructions are based on a multi-proxy approach, including pollen, plant macrofossils, charcoal and testate amoebae. We also use dendrochronological data to compare the peatland record with *Pinus* sylvestris record. Our preliminary results showed that a change in forest management and progressing climate warming affected the development of the peatland. Pollen data revealed that transition from lacustrine to peatland environ took place before the 1930s and progressed along the strongest agriculture activity in the site vicinity. However, 20th century, especially its second part, was a period of constant decline of agriculture and increase in Scots pine dominance in the landscape. Considering the context of forest management and the protection of valuable ecosystems in the monoculture forest area, the study's conclusions are essential for peatland and forest ecology, paleoecology and forestry.

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Multi-proxy paleoceanographic reconstruction of the Mediterranean Sea during sapropel S6 deposition (~172 ka)

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The formation of Mediterranean sapropels (dark-colored, organic-rich sedimentation layers) is not fully understood, but it has been found to be deposited at times of high-amplitude precession minima, which cause changes in the basins' freshwater and heat budgets, limiting bottom water ventilation, and leading to basin-wide anoxia. For this reason, the majority of sapropels are recorded during warm interglacial periods. However, glacial sapropels do exist, such as sapropel S6, which was deposited during the penultimate glaciation (Marine Isotopic Stage 6). During MIS 6 (□132−185 ka), millennial-scale climate variability is suggested to have been present in the North Atlantic and Mediterranean Sea, evidenced by marine, speleothem, and pollen climate record studies, and, more recently, evidenced in more detail by a high-resolution foraminiferal stable isotope record. With this data, we are provided with more insight into the paleoclimatological and paleoceanographic mechanisms behind the deposition of sapropel S6. But, because there are several sources of freshwater input that could be involved during the sapropel formation, more evidence is needed to pinpoint the exact conditions. Here, we present a multiproxy paleoecological study of the sapropel S6 sedimentation layer found in piston core M25/4-12 retrieved from the Ionian Sea of the Eastern Mediterranean basin (EMED). We compiled the data from analyses of planktonic foraminifers, calcareous nannofossils, pollen, dinocysts, and foraminiferal d18O, and compared our findings to the previously mentioned published literature on MIS 6 and sapropel S6. Our multiproxy data agrees with the previously published data indicating that glacial meltwater input from the Alpine glaciers was responsible for preconditioning the EMED for stratification being the result of an interstadial warm period during MIS 6. However, with this additional paleoecological data, we also propose that, immediately after the glacial meltwater, Nile River discharge from enhanced monsoonal activity was the mechanism for sustaining the stratification and bottom water anoxia.

Congo Basin Vegetation Sensitivity to Hydroclimate Shifts During the Pleistocene

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The Congo Basin is the world's second largest rainforest and plays an important role in global convection and carbon cycling. Despite its enormous impact, the Congo is vastly understudied due to political and economic instability. The lack of observational records from the Congo has greatly impacted our ability to predict future climate change in the region. For example, the IPCC 6th Assessment cites low confidence in the current projections of mean precipitation change and drought frequency in Central Africa, resulting in a high level of uncertainty for future rainfall in the region. Rainfall is particularly important in the Congo because it already exists at relatively low levels for a tropical rainforest. Modern satellite data from the Congo has shown an increase in dry season length coinciding with a decrease in forest greenness. With few observational records, and an inability to predict if these trends will continue, paleoclimate studies provide an opportunity to study climate variability and ecological sensitivity in the Congo under past climate conditions. Using dD and d^{13}C of leaf wax n-alkanes, we evaluate the sensitivity of vegetation type to changes in precipitation. Additionally, using alkenone unsaturation ratios (U^{k}_{37}') we reconstruct Atlantic sea surface temperature to investigate the role of the Atlantic in driving Congo Basin hydroclimate patterns. We focus our efforts on the late Pleistocene, which includes MIS 11, one of the warmest and longest interglacials of the last 5 million years and an analogue for future climate change.

Pliocene-Pleistocene environments in the Dacian Basin (S Romania): a stable isotope study of land and freshwater fauna

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Fluvial and lacustrine deposits in southern Romania yielded mammal and fresh water fossil fauna that can contribute to understanding both long and short term regional environmental changes during the Pliocene and Pleistocene.

We present here oxygen and carbon stable isotope data from ostracod and mollusk shells, as well as from mammalian tooth enamel from three main sites: Măru (3.0 Ma), the Olteț River Valley complex (ORV, spanning the 2.2 Ma to 1.1 Ma period), and Copăceni (1.0 Ma).

Moreover, we provide a first radiometric age estimate for Fântâna lui Mitilan site within the ORV complex, based on the LA-MC-ICPMS U-Pb dating of an artiodactyl tooth fragment.

Pollen analysis reveals a typical mesothermic riparian plant association at Măru, while at Irimești (part of the ORV complex) a temperate steppe was present.

Although sparse oxygen isotope data have been previously published from this region, high resolution records that could help understand climate seasonality are needed. We aim to address this issue by studying tooth enamel and mollusk shells at monthly resolution, while also adding data from seasonally molted ostracod valves. Extracting local oxygen isotopic information from freshwater fauna allows us to infer the isotopic composition of precipitation and its sources. Such local information combined with carbon isotope results, will further help us constrain mammalian behaviors regarding migration or feeding.

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The Quaternary record exposed in an open-cast mine of the Kleszczów Graben, central Poland

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The open-cast lignite pits of central Poland present an outstanding opportunity to investigate the Quaternary sedimentary record. Those in the Bełchatów area have been studied by numerous workers since the 1970s, and in 2004 a new pit was opened in the neighbouring Szczerców area. Here we present the results of a range of investigations conducted (2017-22) on the fluvial and lacustrine sediments exposed at Szczerców. These include lithostratigraphy, fossil biota (diatoms, pollen, macroflora, seeds, Cladocera, molluscs), and geochemistry (elemental and isotopic composition) partly constrained with carbon-14 dating. The sedimentary sequence at Szczerców ranges from lacustrine deposits of the Odranian (Early Saalian) marine isotope stage 6 (MIS 6), through lacustrine-peat deposits of the Eemian (MIS 5e) to lacustrine and fluvial deposits of the Early Vistulian (MIS 5d–a) and Plenivistulian (MIS 4–2). Pleistocene glacial tills are also observed together with remnants of an associated Middle Pleistocene(?) proglacial lake. The tills were studied in terms of gravel lithology and rare earth elements in the matrix. We also focus upon the mineral and organic sedimentary infills of palaeolakes formed during three interglacial periods that we postulate represent MIS 15, MIS 11, and MIS 5e.

Granulometric analysis of recent Saharan dust with insight into bioaerosol content analysis

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The arid-semiarid regions of the Earth release billions of tons of mineral dust into the atmosphere and the lifted dust is transported even over vast distances by winds of the global atmospheric systems. Extensive measurement networks and remote sensing methods can determine the main source areas and their geological and geomorphological environments. Although, the potential applications of the individual grain properties obtained from the grain size and shape analysis lie in a deeper understanding of dust transport and deposition processes since the transport mode, distance and deposition mechanisms affect the transported particles. Thus, by knowledge of unique granulometric marks we could also track changes in the environmental conditions for the transported particulate matter by monitoring their morphological parameters. Bioaerosol (diatom, pollen) particles are mixed with the mineral dust, which can also be used to refine the delineation of source areas.
The analysis was carried out on samples from the Saharan source areas (e.g., the Atlas foreland chotts) and from recent years' intense European depositional events from Pyrenees, Alps, Carpathian Basin. Granulometric analyses based on automated static image analysis (Malvern Morphologi G3SE-ID) can be used to obtain direct data on the size, shape and optical properties of the particles, while the built-in Raman spectroscope of the instrument also allows the determination of the qualitative properties (mineral phase) of any individual grains. Particle size of mineral grains from some intense deposition episodes was very coarse with a significant volume fraction of particles >20 µm. The dust grains are generally characterised as atmospheric cooling factors, but once larger particle sizes appear in the calculations, the whole issue turns around. These giant dust particles play a heating role, essentially influencing the radiation equations. By automated image analysis, the pollen and diatom particles of the sediments can also be detected in some source materials and deposited sediments. Using automated image analysis, it is possible to distinguish between the mineral and bioaerosol components of the different sediments based on their shape parameters.
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Pollen productivity estimates for past land cover reconstruction in mountain regions

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Pollen-based land cover modelling have been applied at local, sub-continental and continental scales with a major aim to evaluate the performance of past land use scenarios and to study the vegetation, climate and human interactions through time. However, the application of such modelling in mountain regions is more complex than for lowland ecosystems, in particular because of the challenge to model the dispersal mechanisms of pollen in complex topographic contexts.

A key parameter to use pollen-based land cover modelling schemes such as the REVEALS model and the Landscape Reconstruction Algorithm is the relative pollen productivity estimates (RPPs) for the major plant taxa present in the region. Most RPP studies have been done in lowlands and further researches are required to develop these approaches in mountain. In particular, different pollen dispersal models are now available to calculate alternative sets of RPPs that can be used specifically in mountains.

This study aims at investigating pollen production and dispersal mechanisms for the most abundant plant taxa in the Eastern part of the Alps, i.e. southern Germany, Austria and northernmost Italy. The performance of two approaches in pollen dispersal modelling are here evaluated, namely the Lagrangian stochastic model and the Gaussian plume model. The objective is to create a set of RPPs including spruce, pine, larch, fir, Ericaceae, Poaceae, alder, birch, beech and hazel, as examples. For this purpose, the pollen-plant abundance relationships are assessed in an area covering different valleys and altitudes. Thirty sites were randomly selected within a radius of 50km. For each site, a modern pollen sample (moss polsters) was collected in the center of the site and vegetation surveys were carried out to estimate plant abundance for incremental distances, i.e. incremental rings of 1m from the center to 5km. Vegetation maps were created based on GPS mapping during fieldwork for the 0-100m and then by using satellite images and regional vegetation maps for the distances from 100m to 5km. The extended *R*-value (ERV) model is used for the calculations. The first results are presented in this poster.

Aquatic insects' responses to rapid climate change: a high-resolution chironomid analysis in Lake Mezzano (Italy) sediments during the Last Glacial termination

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The Lateglacial period is characterized by a series of rapid and abrupt shifts in climate that are recognisable in numerous records worldwide, but specially in Central and Northern Europe. Lake sediments are an important source of climate information and may be used for reconstructing past environmental conditions as they are particularly sensitive to the combined effect of climate change and anthropogenic pressures. Indeed, they contain proxies that can provide quantitative, highly resolved temperature data to reconstruct climate dynamics. In this study, a high-resolution Lateglacial chironomid record from lake Mezzano (central Italy) will be analysed. This small deep maar lake is partly varved, allowing a high-resolution reconstruction of environmental changes during the interval of time proposed. Using an existent chironomid-based quantitative inference model developed from two combined calibration datasets from Norway and the Swiss Alps, we aim to quantitatively reconstruct the summer temperatures in Central Italy, during the interval of 15,000 to 12,000 BP which broadly correspond to the Bölling/Alleröd climate event. This study combines bioproxy information with already available information derived from X-ray fluorescence, geochemical and palynological data. Up to date, no chironomid-inferred temperature reconstructions are available from Central Italy. The model will be compared with other regional climatic records to evaluate the coherence of climate patterns during the Lateglacial in the Mediterranean region. Previous results in a stratified lake from northern Italy showed that during the B/A the disappearance of the cold-adapted chironomids together with the presence of low-oxygen -tolerant *Chironomus* is indicating warmer conditions and low oxygen concentrations.

This study underpins previous information about lake productivity, lake bottom anoxia and postglacial climate change especially during these rapid climate changes observed during the warming B/A interval. Therefore, it contributes to our understanding of climatic patterns and of biotic responses to temperature and other environmental changes throughout Europe and the Mediterranean region

Lake system response to annual hydroclimate variability in the East African Rift System between 150 and 100 kyr

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Lake sediments provide useful insight into environmental responses to climate variability over a wide range of timescales from seasons to millennia. Paleoclimate records, including lacustrine records, in the East African Rift Valley show rapid changes from humid to hyper-arid climates during the late Quaternary. Records of such events at annual to decadal timescales are however currently scarce in this region.

This study applies a multi-proxy approach to reconstruct hydroclimate variability at annual to decadal timescales in the East African Rift System (EARS). Diatom assemblages, oxygen isotopes in diatom biogenic silica ($\delta^{18}O_{diatom}$) and bulk X-Ray Fluorescence (XRF) records are used to understand past changes in moisture and precipitation patterns over East Africa as well as changes in lake water chemistry and lake levels. An age model at annual timescales was also developed using high-resolution XRF measurements and layer counts which allow us to study the cyclicities present in the moisture and precipitation patterns over the EARS.

In the current climate change context, understanding how a lake system responds to rapid climatic fluctuations is critical to help mitigate the impacts of a warming planet, which include phenomenon such as droughts and floods.

Understanding changes in plant paleocommunities in the southern Baltic region during postglacial global climatic and human expansion events

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Post-glacial history of the local catchment and surrounding morphology have been analysed taking into account the results of the multiproxy studies of the Dūkštelis Lake sediment sequences. Seven cores were analysed as a result, and their records were synchronized using lithological boundaries as well as magnetic susceptibility data, and consequently, cross-sections of the palaeolake were modeled. The multiproxy investigations of the deepest sediment core (1300 cm) consist of palaeobotanical (spore-pollen, diatom analysis), lithological (grain-size and loss-on-ignition survey), magnetic susceptibility (MS), isotopic (^{14}C, AMS, δ^{18}O and δ^{13}C) studies and geochemical analyses. A detail radiocarbon dating of the section revealed that the area deglaciated much earlier than it was thought before at about 15000 cal yr BP. At the beginning of the Early Holocene, the local climate stabilized. Formation of the dense plant cover inhibited erosional processes. Alongside the closing of the basin more and more nutrients concentrated in the lake which led to its eutrophication while the decrease in oxygen content slowed down the mineralization of organics. At the end of the Middle Holocene, the investigated part of the lake transitioned into the bog state. During the last 1000 years, human settlement strongly affected all near-lake environments. Heavy metals on the top of the sediments show significant pollution levels. An additional study is planned, and it will focus on the quantitative temperature reconstructions based on fossil pollen data and plant sedimentary ancient DNA (sedaDNA). Recent advances in the analyses of plant DNA from fossil samples enabled the molecular reconstruction of palaeofloras and suggest that sedaDNA from lake sediments is a powerful tool. The application of this tool will help us to detect if some species persisted near the lake during time intervals when they are not detected as macrofossils, thus filling the gaps in the macrofossil record. Independent long-term climate variability estimators will help us to understand the mechanisms of changes in terrestrial environments in the epoch of human expansion.

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Polar marine environments and ecosystems under a warming climate: recent deglacial records from the Antarctic Peninsula

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High-latitude regions such as Antarctica have seen unprecedented environmental shifts over the last few decades due to anthropogenically-driven climate warming. Such shifts, perhaps most visibly expressed in the decline of the cryosphere, impact marine ecosystems. Here, we present emerging results from 'CHARME' (Changing AntaRctic Marine Environments), a project funded by the POLS program (National Science Centre Poland & Norwegian Grants; No. 2020/37/K/ST10/04127) focused on characterizing the biogenic proxy signature of recent deglaciation (retreating tidewater margins). Three fjords along the Antarctic Peninsula have been sampled systematically in transects from fjord head to mouth for both surface and short (multicore) sediments; multiproxy analyses include micropalaeontological, biogeochemical, and molecular approaches. In surface sediments, highly-branched isoprenoid (HBI) biomarkers concentrations ($IPSO_{25}$, HBI III, HBI IV) increase with distance from the tidewater glacier. The sea-ice biomarker $IPSO_{25}$, whose surface sediment abundances rise with increasing latitude, shows good correlation with the proportion of sedimentary DNA (sedDNA) of the cyst-producing sea-ice dinoflagellate *Polarella glacialis*. The open-water phytoplankton biomarkers HBI III and HBI IV are most abundant towards fjord mouths, whereas concentrations of sterols such as dinosterol and desmosterol are higher towards the fjord head, closer to the tidewater margin. Benthic foraminifera are abundant and diverse throughout surface sediments, with *Cribroelphidium webbi* confirming its indicator potential for ice-proximal environments. Multicores taken at fjord mouths cover the last ~70-200 years (depending on location), allowing a detailed glimpse into deglacial dynamics. HBI biomarkers show comparable downcore trends, concentrations of the sea-ice biomarker $IPSO_{25}$ increasing over the last few decades in tandem with the sedDNA of *P. glacialis*, in correspondence to retreating tidewater margins.

The Holocene climate changes, fire history and palsa peatland dynamics: case study from Yenisei Siberia

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Our paleoecological study is focused on one of the palsa mires located at the eastern edge of the West Siberian Lowlands (Yenisei Siberia) in the forest-tundra ecotone. Perennial frost mounds, often called as palsas and peat plateaus, are the dominant landscape type in this region. The paleoecological reconstruction is based on high resolution pollen, plant macrofossils, stable isotope and loss on ignition data macroscopic charcoal records and detailed AMS radiocarbon dating from a 8 m long peat sequence, obtained from the palsa mire situated near the town of Igarka (N 67°31'53.77' E 86°38'05.65').

The obtained data show that peat inception in the studied mire occurred at about 6200 cal yr BP during the Holocene Thermal Maximum. The time interval between 6500 and 5360 cal yr BP was characterized by warm and dry climate conditions and the highest charcoal accumulation rate throughout the Mid and late Holocene. The fire return period was 70-120 years that is shorter then at present. The main stages of palsa uplift occurred at about 5360 cal yr BP and 2250 cal yr BP and coincided with the periods of climatic cooling and moistening and permafrost aggradation in the Russian Arctic region. Since 5360 cal yr BP charcoal accumulation in the palsa decreased significantly and in some time interval ceased. The fire return period extended to 1500-1800 years. The increase of the charcoal accumulation rate in the peatland under study occurred at the end of 14th – beginning 15th centuries and then charcoal input declined. We supposed that human induced fires led to the biomass burning. According to historical data the Russian colonization of this part of Siberia began in the 17th century, but the first Russian settlers already found a local hunter population in the area of Igarka. The settlement lies on the banks of the Yenisei River, historically one of the main trading routes in Siberia. During the 20th century wood-using industry and a river harbor were developed in Igarka, was obviously accompanied by active deforestation that led to some reducing the forest fire occurrence.

Mineral magnetic properties of loess–paleosol couplets of northern Serbia over the last 1.0 Ma and paleoclimatic implications

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A systematic rock magnetic measurement is conducted on composite Titel-Stari Slankamen loess section in Serbia, representing one of the most continuous and representative European loess–paleosol sequences spanning the last 1.0 Ma. Magnetic enhancement of Serbian loess follows the pedogenetic model, and is attributed mainly to the SP and SD maghemite. The ferrimagnetic grain size (X_{fd}/X_{ARM} ratio) of the paleosols is roughly constant over the past 1.0 Ma, which suggests that, with the possible exception of S5, magnetic dissolution model is not applicable. Therefore, environmental magnetic parameters of these loess deposits can reliably be used for paleoclimatic reconstruction.

Two new proxies, normalized $dJ/dT_{@120K}$ and normalized $\chi_{heating@530°C}$ was first time applied in Serbian loess. They are more sensitive to pedogenesis or low-temperature oxidation in more arid conditions compared with other commonly used magnetic proxies related to the concentration of pedogenic magnetic minerals. The long-term upward-increasing trend in normalized $dJ/dT_{@120K}$ and normalized $\chi_{heating@530°C}$ indicates a stepwise aridity trend during the past 1.0 Ma, with a major step at ∼0.6–0.5 Ma, which is consistent with records from Central and East Asia. The expansion of Northern Hemisphere ice sheets was possibly the primary forcing factor of the aridification trend over the past ∼1.0 Ma.

Dinoflagellate cyst assemblages as a paleoenvironmental and paleoclimatic proxy for the Quaternary shifts of the Gulf of Corinth (NE Mediterranean Sea)

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M0078 core, recovered during the IODP Exp. 381, is located in the central part of the Gulf of Corinth in central Greece. The Gulf now is connected to the open sea, but in the past, was repeatedly isolated and reconnected to the Mediterranean Sea, during glacial/interglacial cycles, through the 60m shallow Rion sill at its western part (<400ka BP) or through the Saronic Gulf, at its eastern part (>400ka BP). These alternations between marine and (semi-)isolated intervals and their impact on local aquatic ecosystems were investigated through the palynological analysis of the site M0078 deposits, focusing on organic-walled dinoflagellate cysts. Dinocysts are an excellent proxy for palaeoenvironmental reconstructions, as they are sensitive to shifts in the environmental conditions and thrive in a wide range of climatic conditions and habitats, from fresh water to the open ocean.
In the present study, the 610 meters long sequence of site M0078 core was regularly sampled at a mean 2m interval, covering several climatic cycles since the Middle Pleistocene. More than 400 samples originating from marine, isolated, and transitional intervals were analyzed. The microscopic analysis documented the presence of more than 35 different dinocyst species. Two major ecogroups were distinguished, presenting alternations between marine and isolated/brackish conditions. The marine intervals are characterized by high dinocyst diversity, while the brackish intervals are characterized only by the presence of the low salinity indicators, such as *Spiniferites cruciformis, Pyxidinopsis psilata, Caspidinium rugosum, Impagidinium caspienense* and *Lingulodinium machaerophorum* (with processes <10μm). In several samples, *S. cruciformis* is dominant, characterizing the assemblage as monospecific. The alternations between marine and brackish conditions recorded in the Gulf of Corinth reveal changes in surface water salinity and temperature, in response to the Quaternary glacial – interglacial cycles. These seem to be in good agreement with global sea-level changes and trace orbital driven climate shifts as shown in the global Marine Isotope Record.

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Vegetation dynamics through successive glacial-interglacial cycles in a unique Mediterranean setting (Gulf of Corinth, Greece)

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The sedimentary record of site M0078, located in the Gulf of Corinth, was retrieved during the IODP Exp. 381. The Gulf of Corinth is a semi-enclosed basin, sensitive to Quaternary climatic oscillations and sea-level fluctuations and was repeatedly isolated from and reconnected to the Mediterranean Sea (McNeill *et al.*, 2019a). In the present study, the 610 meters long sequence of site M0078 core has been sampled for palynological analyses at ~2m intervals aiming to obtain a millennial temporal resolution and more than 140 samples have been studied. The dinocyst assemblages encountered in the same samples by a parallel study, record distinct alternations between marine and brackish conditions in the Gulf in response to global sea-level changes and can be correlated with global Marine Isotope Stages. At this Mediterranean setting, the vegetation response during these glacial/interglacial cycles appears to be more complex in comparison with the aquatic ecosystem. The present study traces the unique shifts in vegetation composition and succession of Mediterranean species in the southernmost Balkan tree refugium at a millennial scale since the Middle Pleistocene. Interglacial intervals show high terrestrial pollen concentration suggesting an increase in plant biomass and vegetation cover, while, during glacials, both the pollen concentration and the tree percentages show a decreasing trend, which is encountered in most southern European records. However, the glacial intervals retain surprisingly high abundances of both the deciduous and sclerophyllous vegetation components, which has not been previously reported. Another remarkable feature of the Corinth record is the occurrence of several Neogene relict tree taxa within the catchment until the Late Pleistocene. These findings together with the longer persistence of relict species confirm the uniqueness of the Corinth Gulf terrestrial ecosystems and the refugial character of the area and allow comparison with other regional reference Balkan sites such as the Lake Ohrid record (Sadori *et al.*, 2016; Donders *et al.*, 2021).

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Project: Quaternary Environmental Changes in the Corinth Rift Area: the IODP 381 palynological record (QECCoRA).

Influence of methane release on the composition of organic matter and benthic foraminifera of Brazilian continental margin (SW Atlantic)

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The continental margin sediments store large amounts of CH_4 in hydrate deposits. The potential dissociation of gas hydrate layers by environmental changes (ie., changes in sea surface temperature) represents a source of CH_4 that can drastically affect the carbon cycle and Earth's climate. Understanding the biogeochemical parameters that control the dynamics of CH_4 infiltration in these environments is fundamental for the prediction of possible impacts and consequences of the destabilization of these deposits. The CH_4 exudation imprints a differentiated geochemical signature on marine sediments deposited in areas under gas escape. Analyzes of total organic carbon (TOC) concentration, $\delta^{13}C$, TOC, and the isotopic signature of benthic foraminifera have been widely applied in the characterization of environments associated with CH_4 release and in the past reconstructions of exudation activity. However, the ecology of benthic foraminifera in environments associated with CH_4 exudation remains uncertain. The present study aims to explore how CH_4 infiltration in marine sediments affects the chemical composition of sediments and the community of benthic foraminifera from pockmarks and from the Alpha Crucis Carbonate Ridge, CH_4 seepage zones, in the southwestern margin of Brazil (between 24° and 34°S). The TOC, isotopic signatures of $\delta^{13}C$ and $\delta^{15}N$ of organic matter, and living benthic foraminiferal assemblages (Rose Bengal stained, fraction > 63 µm) in surface sediments from ten stations will be evaluated. The foraminifera data will be combined with TOC, $\delta^{13}C$, and $\delta^{15}N$ analyses, providing a proxy calibration (ie., key species associated with CH_4 exudation) that will be applied in the reconstruction of the last 200 years of CH_4 exudation activity in a sedimentary record retrieved in the same area. This study will provide data on the composition of organic matter and benthic foraminifera from the Southwest Atlantic in CH_4 exudation zones and on possible anthropic impacts and environmental changes in the evolution of hydrate deposits.

Resolving the Younger Dryas climate event in Siberia and the Russian Far East.

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Siberia and the Russian Far East (SRFE) contain globally important biomes which are established as being responsive to, and a critical driver of local and global climate.

However, due to observational difficulties there remains an incomplete understanding of the complex interactions and feedback between climate, biosphere, atmosphere, oceans, and land in the region.

As such many studies have looked to past examples. The Younger Dryas (YD; G S1: ~12,900 – 11,700 cal. Yr. BP) is conventionally attributed to changes in the Atlantic Meridional Overturning Circulation (AMOC) affecting the North Atlantic sector (NAS) most strongly. In the NAS large-magnitude and rapid climate change at the end of the YD is viewed as an analogue for near-future warming, though the specific chain of earth-system processes that drove it differ from contemporary mechanisms. But, YD responses in proxy temperature and moisture data vary in space and time in SRFE in relation to latitude (insolation), longitude (continentality), topography, suggesting multiple controls.

We present the results of a broad syntheses of terrestrial and marine proxy palaeoclimate and vegetation records from SRFE and adjoining regions spanning the late glacial, including the YD, and early Holocene (ca. 14,000 – 10,500 yrs. BP), with the aim of distinguishing temporal and geographical patterns in climate responses and testing hypotheses on the likely degree to which different components of the global climate system drove such changes (i.e. Asian Monsoon system, Atlantic and Pacific climate-ocean system).

Seventy proxy records were selected for adequate chronologies (at least one before, after and during the YD) and resolution (at least 2-3 samples) through the YD. Calibrated age-depth models for data sets with uncalibrated radiocarbon dates were done using R package ‘Bacon’ with IntCal 20.

47 sites with pollen data were used to examine shifts in vegetation across the region. Other sites reported faster-responding proxies, including atmospherically driven isotopes ($\delta^{18}O$), lake productivity-driven geochemistry ($\delta^{13}C$, TOC, TN), the remains of short-lived organisms (chironomids, diatoms, foraminifera), elemental geochemistry and alkenones.

Initial results show a stronger YD response in the West and North and a muted response in the South and East of the region.

Reconstruction of Holocene hydroclimate and vegetation from geochemical and biogenic proxies, Marais geluk wetland, Free-State, South Africa

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The Holocene climate history of Southern Africa still remains inconclusive despite an increasing amount of proxy records from the region. This might be related to the diversity of proxy records, how the proxies are interpreted, or that some proxies (e.g. vegetation) respond to more than one forcer (e.g. hydroclimate, fire, temperature). Here, a 175 cm peat sequence from Free-State, South Africa, was analysed for isotopic ($\delta^{13}C$), elemental (CS-XRF), mineral (pXRD), molecular (FTIR-ATR), grain size (Malvern 3000) and GSSC phytolith composition. The chronology was retrieved through AMS radiocarbon dating (n=7). The IR signal enabled identification of the main inorganic (clays, biogenic silica, quartz, iron oxides, gibbsite) and organic (fresh OM, carboxylic OM, OM-clay associations, and charcoal) peat components. The result indicate that the early Holocene was dominated by silt sized, minerogenic, sediments, indicative of fluvial transport. The $\delta^{13}C$ values indicate that a mix of trees (C_3), shrubs (C_3) and grasses (mainly C_4) existed in the surrounding landscape during this period. Taken together, the results suggest that mostly moist conditions prevailed in early Holocene. After 8000 cal BP the organic content and biogenic silica started to increase while the grain sizes continually decreased, likely reflecting increased productivity and a successional change from mainly minerogenic sedimentation, towards organic accumulation. After 6000 cal BP the $\delta^{13}C$ values became less depleted, indicative of increasing (C_4) grasses and less trees and bushes (C_3) in the landscape, suggesting that increasingly dry conditions prevailed. Less depleted $\delta^{13}C$ values are sustained between 4070 and 2250 cal BP (~18‰) reflecting a dominance of C_4 vegetation, while the phytolith data indicate that a mix of C_3 and C_4 grasses persisted in this phase. The IR results record increased quartz and charcoal content during this period, suggesting dry, erosive conditions and increased fire activity. The grain size data show highly variable results during this period (mode: 5–25 µm). The last 2000 years are characterized by increased variability, both in productivity, vegetation, and mineral input, suggesting variable hydroclimatic conditions, in line with previous studies of the region.

Sub-decadal scale environmental responses to hydro-climatic changes in the Middle Atlas Mountains, Morocco – learning from historical sources and a high-resolution multi-proxy lake sediment record

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The Western Mediterranean region including the North African desert margin faces major environmental challenges in the context of global climate change in terms of rising temperatures, a higher recurrence of drought events and a decrease in annual precipitation. Additionally, human activities have significantly altered the montane landscape over the past century through deforestation and agricultural practices.
As a condition to state further prospects, it is crucial to comprehend past and present hydro-climatic patterns and their geo-ecological impact. The Moroccan Middle Atlas is considered a transition zone between the Atlantic, Mediterranean, and Saharan air masses, and is therefore of unprecedented interest in order to comprehend regional climate variability and to assess emerging hydrological, geomorphological and ecological impacts.
Despite the growing number of limnological studies from the Middle Atlas, there still is a strong need for coupling palaeolimnological results at the sub-recent time scale with historical cartographic information, meteorological data, and underlying climatic forcing. Lake Sidi Ali (33°03' N, 5°00' W, 2080 m a.s.l.) provides a unique archive for understanding environmental changes throughout the 20th century. At least during the past 100 years, the lake has experienced at least three significant lake-level changes in the order of several meters. We were able to reconstruct and semi-quantify these alternations with the help of historical sources, topographic maps, and satellite imagery. In addition, we implemented a multi-proxy analytical approach on a 145-cm long sediment record, including pollen, $\delta^{18}O$ and $\delta^{13}C$ analysis of ostracod shells and CNS elemental analysis. A reliable age model based on 25 ^{210}Pb measurements and one radiocarbon dated cedar needle enables the correlation of sediment geochemical variations to lake-level changes.
We examined meteorological precipitation and temperature data to evaluate their influence on these fluctuations. Furthermore, we have indications for a temporal coupling of Atlantic climate patterns (North Atlantic Oscillation, NAO; Atlantic Multidecadal Oscillation, AMO) with Sidi Ali's lake-level variations and we provide a more detailed insight into the responsiveness of local vegetation to the climatic and anthropogenic changes of recent decades. This study will thus help to better elucidate the interactions of lake hydrology and vegetation response to future environmental change.

Quaternary glauconitization process on the Guadiana shelf (Northern Gulf of Cadiz)

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Clay minerals are major constituents of materials deposited in marine environments. Green-clay (glaucony) authigenesis, particularly in the marine and diagenetic realms, has played an important role in the understanding of Cenozoic climates. However, the genesis, depositional setting and paleoenvironmental implications of glaucony occurrences in the continental shelves/margin off southern Iberian Peninsula are loosely constrained. In this study, Holocene glaucony grains extracted from a sediment core retrieved from a highstand muddy depocenter off the Guadiana River, northern Gulf of Cadiz, were investigated by digital microscopy, X-ray diffraction (XRD) and electron microscopic methods (SEM-EDX and TEM-HRTEM). This multi-proxy approach allows to assess the physico-chemical conditions that prevailed during the glaucony-forming process in the northern Gulf of Cadiz, and to establish paleoenvironmental conditions that favoured glaucony formation during the recent Holocene highstand.

In the studied sediment core, glauconitization occurred mostly by the replacement of faecal pellets during ~4.2-1.0 cal. ka BP. XRD and TEM-HRTEM analyses indicate that glaucony consists mainly of R1, with minor presence of R0, smectite-rich (nontronite with minor berthierine layer) interstratified glauconite-smectite. It consists of 35-75% glauconitic layers and 65-25% of interstratified smectite layers. The occurrence of shallow radial cracks in the pellet surface along with globular and caterpillar-like biomorphic to low packing density lamellar-flaky nanostructures, mineralogical properties, and K-poor content (~0.4 atoms p.f.u.), indicate a low mature glauconitization process. The mineralogy, chemistry and detailed morpho-textural properties demonstrate that glaucony has formed *in situ* (autochthonous). Conditions for the Holocene glaucony authigenesis occurred in an open-shelf environment at water depths of ~70 m, under suboxic, partially reducing conditions near the sediment-water interface. These environmental conditions were triggered by protracted low sediment supplies and recurrent winnowing action. Furthermore, our dataset provide evidence that (bio)availability of iron was not a limiting factor for glauconitization at our study site. There, iron was supplied by alteration of continent-derived minerals (from natural to anthropogenic weathering) and from ferruginous-rich upwelling waters.

Direct but delayed positive correlation between dolomite and calcite ratios in Lithuania lake sediments and the climatic signal in the Greenland GISP2 record

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The Late Pleistocene to the Holocene is a time interval that covers the climate transition from a cold to a warm interglacial regime. Many studies have focused on estimating environmental responses to climatic forcing in the Baltic region using palynological and stratigraphic proxies of glacial and periglacial settings. Ūla River Valley crosses the outwash plain formed in front of the former ice margin South East from the distal slopes of Baltic highlands of the Pomeranian stage of the Last Glaciation. Deposits in the distal part of the outwash plain are drifted, forming high dunes in many places. In the Ūla River Valley, there are several outcrops with sandy deposit sequences, including peat, gyttja and calcareous sediments interbedded between the sand layers. Herein we describe the mixed lacustrine-aeolian succession of the Zervynos-2 section (southeastern Lithuania), located in the northeastern part of the European Sand Belt. The succession and the sedimentation styles were characterized by granulometric parameters, structural features, dolomite/calcite ratio, and the paleobotanical macro-remains. Our analyses revealed that the Zervynos-2 paleolake formed on the sandur (outwash) plain during the final stage of the Pleistocene. The sudden submergence of a sandbody-constrained paleovalley caused the onset of lake sedimentation. Carbonate ratios and macro-remains from the lower gyttja material showed the presence of substantial millennial-scale oscillations, which suggests a delayed response to the isotopically derived paleotemperatures. The transition to the fast sand sedimentation started approximately in the Middle Holocene and is interpreted here as being caused by the warming and drying of the climate in the Baltic region. The upper Holocene portion of the section represents the transition to exclusively aeolian sedimentation with lower accumulation rates likely related to a long-term cooling trend. The results support the conjecture that there is a direct but delayed positive correlation between dolomite and calcite ratios in lake sediments and the climatic signal in the Greenland GISP2 record.

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Keywords: European Sand Belt, sand, carbonates, plant macro-remains, climate events, Bayesian inference.

Initial approaches to histotaphonomic change in submerged wetland landscapes. The case study of the GNLQ1 extinct faunal assemblage

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The exceptional nature of the site GNL Quintero 1 (GNLQ1) located on the coast of central Chile, as the only submerged Late Pleistocene landscape reported for the south-eastern Pacific coast to date. Makes understanding the nature of its faunal assemblages in regards to their depositional dynamics, paramount to clarify how and why these kind of fossil records were preserved in such particularly fragile and shallow deposits. GNLQ1 deposit presents itself as a challenging sample from a taphonomic perspective due to its association with both lacustrine/wetland and maritime exposure conditions. Due to ongoing discussion in the literature about how to compellingly understand patterns of surface submarine modification together with the complicated dynamics that potentially produce osteological assemblages in these types of lacustrine environment shorelines, we opted for an initial approach centred around histotaphonomic modification to understand the diagenetic alterations that the samples underwent in these particularly exceptional conditions. A selection of the dated sample between 28-21ka consisting of Artiodactyls (*Paleolama* sp., *Lama gracilis*, Cervidae), Perissodactyls (Equidae) and Xenartrans (Folivora) were embedded in clear resin and cut in 30 µm thin sections, which were ranked afterwards according to histoanatomical integrity of structures using the Oxford Histological Index (OHI), stemming from this different varieties of microscopical modifications related to bacterial, mycological and cyanobacterial modification were recorded, to which finally a broad measure of cracking, sediment or crystal inclusions and potential collagen content was assessed. Overall, the histotaphonomical recorded variables in the selected sample coincide with the current interpretation of sedimentation under freshwater/wetland conditions observed particularly in the presence of subaerial modifications, on the other hand the onset of maritime related modifications might have appeared coinciding with the exposure of the Late Pleistocene – Early Holocene bone assemblage in the Mid Holocene marine transgression, exposing the GNLQ1 sample to marine fouling in relatively recent times.

Middle Miocene development of the modern-like Antarctic Circumpolar Current.

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The Antarctic Circumpolar Current (ACC) is a key component of Earth's climate system due to its strong influence on the global overturning circulation, ocean heat and CO_2 uptake and storage. The timing and mechanisms of the development of a homogeneous and deep circumpolar flow remain disputed, despite the critical significance of the ACC for Earth's climate. Here we present neodymium isotope and sortable silt records from two pelagic sedimentary archives in the Southwest Pacific and South Indian Ocean (DSDP 278 and ODP 744, respectively) spanning the last 31 million years (Ma). Our data demonstrate that a modern-like deep-reaching circumpolar current did not exist before the Middle Miocene. This contrasts the long-held convictions that the development of a strong, deep ACC was solely controlled by the opening and deepening of Southern Ocean gateways, and resulted in significant glaciation across the Eocene-Oligocene Transition (34 Ma). We suggest that besides tectonic pre-conditioning, the expansion of the Antarctic ice sheet and sea ice during the Middle Miocene Climate Transition played a vital role in driving intensification of Southern Westerly Winds and establishment of a deep-reaching circumpolar flow.

Middle Miocene East Antarctic Ice Sheet and Southern Ocean interactions.

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The East Antarctic Ice Sheet (EAIS) underwent a major expansion during the Middle Miocene Climate Transition (~14 Million years ago (Ma)), resulting in ~60 m sea-level drop. The drivers of MMCT cooling and associated ice expansion are not fully understood, in particular the role of Southern Ocean dynamics. Here we present new data from two Middle Miocene (~15-12 Ma) marine sedimentary archives recovered offshore Prydz Bay, East Antarctica. By studying Ocean Drilling Program (ODP) Site 1165 located on the continental rise off Prydz Bay (64◦27.27° S, 67◦13.08° E, 3537.5 water depth) and ODP Site 744 located on the Southern Kerguelen Plateau (61° 34.66´S, 80° 35.43´E, 2307 m water depth), we provide new insights into the interactions between the Antarctic Circumpolar Current (ACC) and EAIS dynamics offshore Prydz Bay. Neodymium and strontium isotopic composition of Middle Miocene (~15-12 Ma) detrital sediments from ODP Sites 1165 and 744 were generated to constrain changes in sediment provenance, recording changes in ice sheet dynamics. Neodymium isotope ratios (ε_{Nd}) from fossil fish teeth from ODP Site 744 were used to trace regional water masses and ocean circulation changes for the same period. Additionally, mean sortable silt and biogenic silica records generated from both ODP sites were used to track changes the position and strength of the ACC. Overall, our results indicate that changes in the Southern Ocean played a key role in the behavior of the EAIS during the Middle Miocene.

Towards a UV-B reconstruction using FTIR spectra of Cedrus atlantica pollen; the Holocene record from Lake Sidi Ali, Morocco.

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Ultraviolet-B (UV-B) radiation influences all biological life on Earth and may also influence the Earth's climate systems. Instrumental records of UV-B radiation are relatively short; thus, it is unknown how UV-B has changed over long timescales or what influence this has had. Pollen and spores which are traditionally analysed to identify changing vegetation composition, can also be used as a proxy for UV-B. Compounds within pollen that respond to UV-B radiation (Ultraviolet Absorbing Compounds, or *UACs*) are preserved within sporopollenin in sub-fossil records. These compounds can be measured using Fourier-Transform Infrared Spectroscopy (FTIR), where increased UV-B levels result in greater concentration of UACs, which opens the door towards UV-B reconstruction. We analysed the FTIR spectra of sub-fossil *Cedrus atlantica* pollen grains from a core collected from Lake Sidi Ali, Morocco, with previously published pollen and sedimentary records. Pollen grains were isolated from samples taken at a ~200-year resolution spanning ~11,000 years – no chemical treatments were used for the pollen isolation to preserve the chemical signature of the pollen. We also analysed modern *Cedrus atlantica* pollen collected from across Morocco using the same protocols as the sub-fossil pollen, to use as a modern analogue calibration for the fossil record. Preliminary analysis shows that there have been changes in UAC concentrations over the Holocene, indicating changing UV-B levels through time. However, challenges remain for full quantification of UV-B levels from FTIR spectra, including issues surrounding processing of spectra, identification and quantification of peaks, and comparisons between modern pollen and sub-fossil sporopollenin FTIR spectra. We will compare our results with the Holocene ^{10}Be-based total solar irradiance (TSI) and ^{14}C-based sunspot reconstructions, testing the hypothesis that major changes in solar activity should also be evident in the UV-B record.

Late Pleistocene cryogenic phenomena and their links with cold hydromorphic paleosols in North-Western Siberia as a key to correlate ancient environments

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New data obtained by authors allow them to share the concept that ice sheets never occupied North-Western Siberia over the Pleistocene. It implies development of non-glacial surface processes in this region. Contrary to the south of West Siberia where continuous stratified loess mantle was developed, in North-Western Siberia the sedimentation was more heterogeneous. However it forms a complex largely controlled by permafrost factors, when horizons generated by paleocryogenic processes interacted with paleopedogenesis are spread much more uniformly. They are specific for certain chronological intervals and could serve thus as reliable stratigraphic markers for inter-regional correlation. The authors revealed several major Late Pleistocene stratigraphic levels identified and studied, and accompanied by the indicators of paleocryogenic and cryopedogenic processes in the sedimentary sequences of the high river terraces on both sides of the Siberian Uval, a highland at the right-hand Middle Ob' River's bank. The lowest level identified terrace sections yielded U/Th dates 100-120 ka BP and thus is attributed to the MIS-5 thermochron. It represents a pedocomplex in which the lower paleosol unit has micromorphological signs of clay illuviation (indicative of taiga pedogenesis) whereas the upper one consists of the peat and gleyic horizons – the product of cryohydromorphic pedogenesis. The second (intermediate) pedostratigraphic level lies above the MIS-5 level being separated by the alluvial sediments. Its paleosols have ^{14}C-dates from the soil organic materials in the range of 25-35 ka BP and thus correspond to MIS-3 thermochron. These paleosols show macro- and micromorphological features of redoximorphic processes and frost action indicative of soil development under tundra-steppe ecosystems with permafrost. The third level corresponding to the end of MIS-2 (^{14}C-dates – 10-16 ka BP) was identified in the upper parts of the high terrace sections. Pedosediments filling large polygonal ice wedge pseudomorphs present this strongly gleyed paleosol. In some profiles at least two stages of the ice polygonal wedge development were identified. We are to associate this paleosol development with the warming events at the end of MIS-2. The uppermost level represents the Holocene Podzol complex developed after the surface deposits become thawed: it occurred, according received ^{14}C-dates, 6-7 ka BP.

Investigate Late-Quaternary Meltwater Pulses through sedimentological, micropaleontological and geochemical approach: preliminary results

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Climate changes and sea level rise during the next century are two of the main environmental challenges to face by the modern society. Sea level change responds to a variety of processes including ocean's thermal expansion and ice sheet melting in the polar areas. The latter have been responsible for past abrupt relative sea level rises known as meltwater pulses (MWPs) that deeply changed the Earth's physiography after Last Glacial Maximum by submerging the paleo coastal areas. MWPs are short-lived global acceleration in sea-level rise resulting from intense glacial melting, surge of large ice streams into oceans and intense iceberg discharge during ice sheet disintegration. The main concerns related to the present fast global climate changing is the possibility that sudden drastic ice loss from Greenland and/or in the West Antarctic Ice Sheet would lead to a new abrupt acceleration of the relative sea level rise with consequent inundation of vast coastal areas and/or to cause an abrupt slowdown of the Atlantic Meridional Overturning Circulation (i.e. Golledge et al., 2019). To better understand the dynamics and risks associated with the onset of past meltwater pulses, their impact on thermohaline ocean circulation and climate it is pivotal the geological study of the well preserved and most recent MWP events occurred during the Late Quaternary, particularly those occurred during the Last Glacial Termination. Here, we present some preliminary results of the sedimentological, micropaleontological and geochemical investigation of 4 sediment cores collected on the Western margin of the Svalbard archipelago, next to the Fram Strait.

Pollen productivity estimates for past land cover reconstruction in Turkey

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Quantitative reconstructions of past land cover play an important role to assess the long-term perspectives of climate and anthropogenic land-cover changes. Pollen-based quantitative vegetation reconstructions have been a challenge since the start of palynological studies due to the non-linear relationship between pollen assemblage and the related plant abundance. Pollen-based modelling approaches have been developed to correct this non-linear relationship. In order to use such modelling approaches, one needs to get a reliable set of relative pollen productivity estimates (RPPS). RPP is one of the most critical parameters to apply quantitative pollen-based vegetation models such as REVEALS and the Landscape Reconstruction Algorithm. Most of the RPP has been done in Europe and the northern hemisphere, however, only two studies have been carried out so far in southern France and southeastern Romania for the Mediterranean plant taxa. There is a critical need to increase research about RPPs in the Mediterranean basin to get reliable past land cover and land use reconstructions for this region. Southern Anatolia is an important region for its long history of human settlements and key role in the Mediterranean culture. In order to better understand the relation between plant land cover and land use there, the present study aims at first providing a set of RPPs for Turkey and the Mediterranean region in general that can be used to run the pollen-based vegetation models.In a second step, the resulting set of RPP is used in the REVEALS model runs based on the fossil pollen records collected from Golhisar Lake in Burdur. To calculate the RPP values modern pollen data were collected from mosses and soils from 21 sites within a 50 km radius around Golhisar lake. These data have been combined with the modern regional and local vegetation maps by using the ERV model to assess the pollen and vegetation relationship. We present the first results and their applications to reconstruct past land cover and land use around Golhisar Lake over the last 18.000 years, and we further discuss what this new set of RPPs implies in terms of perspectives for future RPP studies in the Mediterranean region.

The ‘Ona Paleovalley’: A major submarine slope failure system in the southwestern Scotia Sea (Antarctica)

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The southern Scotia Sea hosts several small oceanic basins developed through continental break-up and oceanic spreading during the Cenozoic. Ona Basin is the southwestern most basin of the Scotia Sea. It is bounded by several structural highs: the Shackleton Fracture Zone to the west, Terror Bank to the east, and the South Scotia Ridge to the south. The southern part of the basin is further divided in two sub-basins (the western and eastern Ona basins) separated by the submarine relief called Ona High. The Ona Basin is mainly affected by two major water masses, the deeper branch of the Antarctic Circumpolar Current flowing eastwards and a westward flowing branch of the Weddell Sea Deep Water (WSDW). Interaction between mass movements and contouritic processes are likely to occur as a consequence of the complex geologic, physiographic and oceanographic setting. A combined approach including geomorphological, stratigraphic and seismic analyses allows us to document, for the first time, the record of repeated large-scale submarine landslides in the western Ona Basin. A major morphological feature named as *‘Ona Paleovalley’* is genetically related to large-scale Middle Pleistocene to recent mass movements. Deposition of large-scale mass transport deposits (MTDs) formed a template which guided and fostered major valley incision during the Middle Pleistocene. The valley infill records channelized depositional periods with possible development of turbidites alternating with erosive events when sediments were evacuated basinwards. This morpho-sedimentary pattern is attributed to the interplay between tectonic events leading to gravitational processes and the channelized flow of the WSDW.

Poster - sessions 30, 45, 73, 100, 125, 127, 128, 130, 135, 139, 205, 207

Fossil pollen, spores and non-pollen palynomorphs registered in the sediments of the high-Arctic lake Tenndammen, central Svalbard

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High microfossil diversity of 15 spore and 56 pollen types with 60 non-pollen palynomorphs (NPPs) has been recovered from the lacustrine sediments from Tenndammen (Colesdalen, Nordenskiöld Land, Western Spitzbergen, Archipelago of Svalbard). The core Te2019 (N 78°06.118′; E 15°02.024′, altitude 5 m asl; 85 cm long and 60 mm in diameter) was obtained from the depth of ca 2 m and subsequently studied for sedimentary ancient DNA (*seda*DNA), botanical microfossil (pollen, spore, NPPs) and macrofossil (seeds and tissue fragments) as well as lithostratigraphy, XRF, LOI, grain size analysis, and portable optically stimulated luminescence (pOSL). The microfossil diversity of Te2019 core appeared unusually rich for such High Arctic area. We present 22 plates of about 400 microphotographic images in the form of an illustrated pollen and spore atlas. From the full assemblage, 23 pollen types were recognized as exotic (i.e. extra-regional, not produced in Svalbard), whilst 22 other types were sourced from regional and local vegetation of Colesdalen and Svalbard archipelago. These source plants included a high number of relatively thermophilus tundra plants, those are either only known from Colesdalen (i.e. *Betula nana*) or restricted to a few locations in Svalbard including other sites in Colesdalen (i.e. *Arnica angustifolia*, in pollen – *Arnica/Taraxacum* type; *Polemonium* (*boreale*), *Koenigia* (*islandica*), *Campanula* (*rotundifolia*), *Vaccinium* (*uliginosum*). Local pollen types of four Saxifragaceae species with clear exine sculpture are described: *Micranthes nivalis*, *Saxifraga cernua* type, *Saxifraga cespitosa* type, and *Saxifraga oppositifolia* type. For 12 pollen types (e.g. Caperaceae and Poaceae types, Ranunculus/Coptidium, Polygonaceae indet.) the source vegetation is unclear or has a mixed, regional and extra-regional origin. The 15 most common pollen types are found within the count of the first ca 30 grains, and a linear increase in pollen diversity is observed within the count of the first ca 40 grains which reaches 27 types reaching 47 types at 88-100 grains and at the count of 300 grains, only 9 additional rare pollen types were added. This study can contribute further palynological and palaeoecological investigations in Svalbard and assist to our understanding of the regional and extra-regional pollen diversity in the High Arctic.

115 years of sedimentation – a detailed analysis of reservoir sediments in the Urft Reservoir, central Europe

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Reservoir sediments potentially provide detailed and continuous information on land use and land cover changes and climatic events in in the related catchment area. The Urft reservoir is located in the Eifel Mountains in western Germany and was built between 1900 and 1905. At the time of its construction, the Urft reservoir was the largest reservoir (45.51 million m^3) and drove, with 12 MW, the most powerful water storage power plant in Europe. In November 2020, the reservoir was almost completely drained for inspection work, which enabled detailed mapping and sampling of the reservoir floor and its sediments, respectively. A digital surface model (DSM) was constructed on the base of several UAS (Unoccupied Aerial System) surveys. Topographic maps with a scale of 1:1,000 from the year 1897 were used to reconstruct the valley floor prior to the flooding. By combining these two datasets, the spatial distribution of the sediment thickness accumulated over the past 115 years was assessed. Temporal information, e.g. sedimentation rates, were obtained from several sediment cores from the upper part of the reservoir. Dating of the sediments is based on a detailed Cs-137 chronology from one of the cores. An additional UAS survey was conducted following the catastrophic flooding event in the northern Eifel Mountains in summer 2021 to quantify the flood-related sedimentation by a single event.

Compared to other reservoirs in Europe, the rate of sedimentation in the Urft reservoir throughout the past century is quite homogenous and sediment inflow is relatively low. However, deposition during individual events play an important role. During the event in summer 2021 up to 30 cm were deposited in the upper part of the reservoir - an example for the punctuation of a constant sedimentation rate by a single extreme event. In addition, the anthropogenic influence on the sediments in the form of mining-induced sediment-bound contaminants and the microplastic content was analysed. Preliminary data point to at least one additional extreme inflow event in the late 1980s.

Subsurface framework of the Pozuelo Mound complex – mound architecture

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Archaeological investigations rely on time and labor-intensive excavation techniques. While providing detailed information on ancient lifeways through recovered artifacts and stratigraphic information, the data recovered is very site specific, and often lacks environmental or geological context. Geophysical investigations of a site can provide insight into the possible location of additional, buried cultural deposits, as well as a site-scale context for the area and link the site to the broader setting. These approaches are not mutually exclusive. When paired, they can offer both local and regional insights.

In May and June 2022, a multidisciplinary team of archaeologists, geologists, geophysicists and geotechnical engineers spent 10 days investigating the environmental context of a low-relief, human-constructed four-mound complex south of Chincha, Peru using Electromagnetic Resonance Tomagraphy (ERT) and stratigraphic analysis. Each mound has a relief of 3-5 meters above the surrounding cultivated plain, and is arranged in a roughly N-S orientation. Previous archaeological excavations at the site date the earliest occupation to 900 BCE, with construction and occupation associated with the Paracas Culture. While the site is located in the Peruvian coastal desert, the earlier work found evidence of wetland sediments and vegetation. The focus of the current investigation was to provide a large-scale stratigraphic understanding of the mound architecture to assist in understanding the archeological context and distribution of cultural artifacts.

The team employed an ABEM Terrameter LS2 with 81 pins and spacing between 0.5 and 5 m to acquire ten lines. The results show correlation with stratigraphy reveled in archaeological unit 31 on the southern-most mound, as well as geological information provided by previous excavations. ERT data also shows evidence for a mound-within-a-mound construction in the northernmost mound, which is not observed at other mounds at the site. Supporting results show that basal units in archaeological unit 31 are regional extensive and underlie the area. This paper will present the results of ongoing data processing of data and interpretation.

Subsurface framework of the Pozuelo Mound complex – the environmental context

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In June 2022, a multidisciplinary team of archaeologists, geologists, geophysicists and geotechnical engineers spent 10 days investigating the environmental context of a low-relief, human-constructed four-mound complex south of Chincha, Peru using Electromagnetic Resonance Tomagraphy (ERT) and stratigraphic analysis. Each mound has a relief of 3-5 meters above the surrounding cultivated plain, and is arranged in a roughly N-S orientation. Previous archaeological excavations at the site date the earliest occupation to 900 BCE, with construction and occupation associated with the Paracas Culture. While the site is located in the Peruvian coastal desert, the earlier work found evidence of wetland sediments and vegetation. The focus of the current investigation was to provide a paleo-environmental context for occupation and mound construction, and to develop an understanding of the spatial relationships between the mound structure and the surrounding and underlying alluvial plain. A total of ten ERT lines, with a total length of approximately 600 m, were collected using an ABEM Terrameter LS2 with four cables. Stratigraphic analyses of archaeological excavation data, including a four-meter deep unit in the adjacent alluvial plain and a nearly 5-meter deep unit in the mound, served as ground truth. Surveys utilized the full capacity of the system's 81 data points. Pin spacing varied between 0.5 and 5 m, depending on the purpose of the survey and length of the survey line. Five lines were located on the southern-most mound (Mound D) to link the excavation and underlying stratigraphic information to the geophysical data. Five additional lines were acquired on the third mound to the north (Mound B) to examine subsurface mound architecture and help establish the regional subsurface stratigraphy.

Stratigraphic analyses suggest basal sediments are fine-grained, water-lain deposits overlain by a thick clay layer, overtopped by aeolian sands, with approximately a meter of mound fill at the top. Deposits underlying the mound showed evidence of liquefaction, likely the result of strong seismic shaking.

This paper will present results from the joint ERT surveys and stratigraphic analyses, and the project's effort to provide a geological and environmental context for the archaeology of the site.

Middle Dniester canyon as a refugium for Gravettian communities – case study: Doroshivtsi III site (Western Ukraine)

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The Doroshivtsi III site is one of the Late Gravettian sites in the Middle Dniester valley. Our research (2019, 2021) was a continuation of the work in 2006-2010. The site is associated with a Late Pleistocene low terrace on the right bank inside the canyon, overlain by loess-like sediments. The sequence in the upper part, to a depth of ~5 m, comprises stratified, carbonate aeolian-colluvial sediments, consisting of silt, sand and clay in variable proportions and subordinate admixtures of local rock detritus in small solifluction lobes. These sediments (20-22 ka age) are poor in archaeological artefacts. Lower to about 12 m depth there are two sets of palaeosols separated by a package of periglacial stratified silty-sandy sediments. The upper set is formed by a series of thin soil horizons ranging from an incipient pedosediment to a well-developed tundra-gley type, which are overlain or separated by loess layers. Their OSL age is 24-41 ka. Artefacts occur in several levels of this part of the sequence, particularly intense in the 6.2-8.2 m interval. Few remains of small mammals were found in sediments between 5 and 8 m. The lower pedocomplex is formed by two interstadial soils. Below this is a series of slope sandy-silty sediments (~4 m) resting on channel gravels (~3 m).

Seven cultural layers were distinguished during the 2006-2012 survey; ten, much poorer – in 2019 and 2021. The data suggests that the number of layers distinguished during the older survey should be reviewed. All levels with artefacts contain numerous animal bones mainly of mammoth, reindeer and horse; a higher than expected proportion of mammoths with *in situ* deceased individuals was observed. Most of the calibrated radiocarbon dates are associated with the LGM (HS-2). Two underlying layers with artefacts were also identified, a higher possibly Gravettian and a lower indeterminate Upper Palaeolithic level. It is not easy to correlate the geological and cultural layers determined during the previous and current research.

Research carried out as part of the grant of National Science Centre, Poland (2018/31/B/HS3/03125) "Environment and culture of Gravettian and Epigravettian gatherers and hunters in the Middle Dniester valley".

Environmental and climatic changes in the Nihewan Basin, NE China, during ca. 1.7 to 0.9 Ma

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The thick Pleistocene sediment sections of Nihewan Basin in NE China are intensively studied since ca. 100 years because of its rich mammalian fossil record and abundant stone artifact-bearing layers. They provide a detailed terrestrial sediment archive for reconstructing the palaeoenvironmental changes during early times of hominin occupation in East Asia. To better understand the mechanisms underlying past climate and environmental changes in the basin, three sediment sections at the Dachangliang location were lithologically investigated at centimetre scale and sampled for the application of a multi-proxy toolbox of sedimentological, magnetic susceptibility (MS) and micropalaeontological analyses. Observable variations in grain size, colour, sedimentary structures, concentrations of magnetic minerals and the ostracod assemblage were identified. The exposed sediments are lithologically mostly relatively homogeneous, they partly include laminations of various thickness, horizontal and ripple bedding, and bioturbation features. They mainly represent varicoloured silt-sized materials of probably reworked loess deposits, partially interbedded with fine-grained sand layers and minor contributions of clay-sized particles. The partly carbonate-rich, light olive gray/pale-brown silts have MS values, whilst high MS values are recorded in yellowish-brown silts/fine-grained sands. These sediments are interpreted to have accumulated in wetlands alternating with deposition on an alluvial plain, and with a lacustrine setting which probably existed from time to time. These different depositional settings are inferred based on the quantification of three dominant grain-size components and the ostracod-assemblage changes (mostly *Limnocythere flexa*, *Ilyocypris* spp. and *Leucocythere* sp.). We correlate our sections with two proximal Palaeolithic artefact-bearing sections (Majuangou and Xiantai) with published magnetostratigraphic data. The correlation shows that our investigated sedimentary sequence was probably formed between ca. 1.7 and 0.9 Ma. The recorded ostracods of laterally apparently consistent white marl beds (dominantly *Cytherissa lacustris*) were used to stratigraphically correlate these sections. The generated long, continuous synthetic sedimentary sequence represents three main wetter periods with three intervening drier intervals, possibly coupled with interglacial (S_{24}, S_{20}, and $S_{9\text{-}1}$) and glacial (L_{24}, L_{20} and L_9) periods which were previously inferred from the palaeoclimatic records of the Chinese Loess Plateau in the southwest of the Nihewan Basin. The inferred climate cycles were probably driven by Milankovitch astronomical forcing.

Al Qawd, the first stratified profile in Duqm, south-central Oman.

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The Late Pleistocene landscape evolution of South-eastern Arabia has important implications for modern human settlement patterns; however, these are currently under-studied and represented by a limited number of securely dated stratified archaeological sites. The region of Duqm in south-central Oman, Al-Wusta Governorate, completely lacks any dated archaeological material older than the Early Iron Age, despite an apparent wealth of visible surface lithic scatters. Here we present the region's first OSL-based chronology of a stratified sedimentary profile with in-situ lithic artefacts. The Al Qawd site is located 15km westwards (inland) from the modern port of Duqm and is in an area with high-quality chert nodules (a valuable lithic tool raw material) present throughout the landscape. The area features frequent lithic scatters of heavy bifaces and unidirectional large and heavy blades, suggesting long-term use of a uniform technology, or/and high-intensity episodes of the same lithic tool production over a short period of time. Up until now, the chronology has been based on lithic typology (there were previously no radiometric dates), with a postulated span from the Middle and Early Upper Palaeolithic, to the Holocene, based on the minimal presence of the surface patina on some artefacts. This study brings together a variety of complimentary geoarchaeological techniques on a range of scales: from broadscale remote sensing to identify landforms (and their likely chronological order), down to site level stratigraphic and dating techniques. The OSL dates from this study provide insight into the chronology of the Al Qawd lithic scatters and, therefore, the landscape evolution of this part of the Duqm region, informing on how the lithic sites fit into the broader landscape of the region. The results contribute to our knowledge of population dynamics and settlement patterns across the Arabian Peninsula during the transition from the Late Pleistocene to Holocene. The research was conducted as a joint effort of ARDUQ and LARiO expeditions in Oman.

The Roman burgus at Trebur-Astheim and its relation to the Schwarzbach/Landgraben watercourse (Hessisches Ried, Germany) – geophysical und geoarchaeological investigations

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The Romans carried out early river regulation and water management in the Hessische Ried in the 1st century AD. Roman waterways enabled the transportation of troops and material and were of strategic importance to secure the territory of the Roman Empire. Small fortlets, so called burgi, were constructed along the tributaries of the River Rhein. The fortlet at Trebur-Astheim represents such a Roman military site along the Rhein-Limes. Its construction is dated to AD 364/375 and was part of the building program realized during the reign of the Emperor Valentinianus IThe archaeological site is located at the Schwarzbach/Landgraben watercourse which connects the western fringe of the Odenwald with the city of Mogonatiacum/Mainz.

Multi-method geophysical prospection was carried out at the burgus at Trebur-Astheim. We were able to trace the ground plan of the late Roman fortlet showing a rectangle building at the center with a wing wall to the northern and the southern side running towards the present riverbank. On this base, detailed geomorphological and geoarchaeological studies were carried out to clarify how the burgus was connected to the watercourse of the Landgraben/Schwarzbach, to collect information on the structure and function of the building and to establish a local geochronology.

Our results show that the burgus was constructed at the very edge of the Lower Terrace directly facing the watercourse. In front of the burgus, a semi-enclosed artificial basin was detected. Sediments prove that the burgus must have been open towards the fluvial system and that the burgus was not enclosed by a wall from the western side. Based on stratigraphic data, the protruding nose-type Lower Terrace section in between the wing walls was modelled as ramp into the burgus basin to pull vessels on the artificial river bank. There are two different burgus-related sedimentary facies, namely a lower moderate to high-energy fluvial facies right on top of Lower Terrace sands and a subsequent fluvial facies reflecting a clearly reduced flow velocity. The final phase of use of the burgus was dated to the time period 425-599 cal AD. It was thus in use for maximum ca. 235 years.

Holocene landscape reconstruction in the surroundings of the Temple of Pepi at ancient Bubastis, southeastern Nile Delta (Egypt)

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For temples in ancient Egypt, sacred water canals or lakes that provided water for many types of religious rites and other activities were very specific and important features. In recent years, two of these sacred water canals have been demonstrated for the Temple of Bastet in ancient Bubastis. It has now been investigated whether sacred water canals also flowed around the Temple of Pepi (2300–2250 BCE), located approximately 100m to the northwest, and whether there is a direct connection to those at the Temple of Bastet. To explore the Holocene landscape genesis of the Temple of Pepi, 15 drillings and 8 ERT measurements were carried out in the surrounding area. The results show loamy to clayey sediments in deeper sections of all drillings with a maximum thickness of 1.70m, indicating a marshy or swampy depositional environment. Based on the ceramic fragments found in these deposits, which can be roughly dated to the Old Kingdom (2850-2180 BCE), the area around the Temple of Pepi was most likely characterized by a marshy, swampy landscape during the early construction of the temple. In the course of time, this areal fell dry or was deliberately drained for its subsequent use for occupation. Regarding to the original research question, there is no evidence for a direct connection to the canals of the Temple of Bastet yet.

Humans and waters in Vix/Mont Lassois (Burgundy, France): geoarchaeological questions and methods to investigate a vital resource between opportunities and risks

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The last years of archaeological research at Vix (Burgundy, France) have confirmed the exceptional character of this princely site dating from the Hallstatt period (800 BC – ca. 450 BC). Large residential buildings and oversized fortifications do not only exist on Mont Lassois, as previously established, but similar structures extend into the alluvial plain of the Seine River at the foot of the hill. These new discoveries raise important geoarchaeological questions related to the interactions between humans and the river, and beyond that between humans and water.

Water is a necessary resource for drinking, agriculture, and livestock. It can also be used for many practices (e.g. fortifications, craft productions, navigation, even religious rituals). However, these opportunities are accompanied by risks due to fluctuations in river regime: low water or drought cause stress on availability of the resource, floods or river displacement can lead to destructions. Faced with these, the adaptation and resilience of populations must be examined through interdisciplinary multi-scale methods.

This approach focuses on the Hallstatt settlement, from individual structures to the entire site and its surroundings, but diachronic occupations are also considered. Various geoarchaeological tools are deployed, including sedimentary coring (stratigraphic interpretation, macro-remains analysis, 14C dating), geophysical and geotechnical survey (electrical resistivity tomography and dynamic penetration testing), Lidar and topographic analyses, follow-up of excavations and inventory of archaeological reports. Results allow us to trace back the movements of the Seine course over time, to provide arguments for interpreting archaeological structures and water uses. By reconstructing past soil surfaces, we can also assess erosion/deposition rates and discuss the potential of preservation at different locations. Moreover, models can be proposed regarding changes in hydrological dynamics, landscape evolutions, response to hazards and consideration of water in land uses.

Buried landscapes of the Avon Valley and the Mesolithic of the Stonehenge Area.

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Whilst the Stonehenge landscape's iconic middle-later prehistory has recently been revealed in even greater detail and breadth, its pre-monumental environmental and archaeological history remains largely hidden. Was the Stonehenge monumental landscape, including cursuses, henges, settlement and Stonehenge itself developed in an empty landscape? What was the scale of pre-Neolithic activity, and how dynamic was the environment during the mid-later Mesolithic? Recent excavations along the River Avon at Amesbury, Wiltshire have revealed a buried potential to provide the Meso-Neo environmental context for the eastern part of the World Heritage site. This project has utilised ground-breaking methodologies including direct-push penetrometry, UAV-borne Lidar, pOSL/IRSL and sedaDNA to investigate the pre-Neolithic fluvial-terrestrial hinterland environment of the eastern part of the Stonehenge World Heritage Site (SWHS) from Durrington Walls to West Amesbury and extended the context across neighbouring catchments with confirmed Mesolithic activity and environmental potential.

Key research questions which have been addressed during this project include, how open the Mesolithic environment was, and how did the species mix change over 4000 years prior to the 3rd millennium BC? Was pine dominant, or was it decreasing in the Late Mesolithic? Is there evidence of pre-Neolithic human landscape and resource management and did this change over the course of the Early to Late Mesolithic? Was hazel managed or facilitated by human activity or related to climate and hydrology? What role did large herbivores, particularly Aurochs (*Bos primigenius*), play in the Mesolithic environment and what is their archaeological significance? Can a step-change be seen in vegetation and erosion/sedimentation in the Mesolithic-Neolithic-early Bronze Age periods and how does this relate to soil history and archaeological visibility? The answer to these questions will provide us with a much deeper contextualisation of the uniqueness and supra-regional significance of the monumentality of Stonehenge.

Keywords: Mesolithic, Stonehenge WHS, Buried Riverine Landscapes, SedaDNA, Palaeoenvironments

Shell middens as important archaeological and palaeoenvironmental archive – a case study from western Poland

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Shell middens are common finds recorded at Polish archaeological sites dating from the Neolithic to Iron Age; however, very little is known about the acquisition and exploitation of mussels by prehistoric communities. An archaeological feature discovered recently at Kiekrz (western Poland) has given us a rare opportunity to conduct complex research on a representative and large sample. Our study aimed to recognize the pit's function, the shell deposit's character, its chronology, the season of shell collection and the environmental conditions that prevailed in the settlement's time. The investigations included multi-faceted analyses of archaeological finds (pottery, animal bones, and mollusc shells), charcoal remains, $\delta^{13}C$ and $\delta^{18}O$ shell composition, and ^{14}C dating. The research results indicate that shells of *Unio* were deliberately collected for food ca. 1500 cal. yr BC. They were probably harvested during late summer from the nearby lake. Then the molluscs were steamed in a kind of earth oven. Pine and oak wood from the immediate vicinity was used as firewood during the molluscs' processing. After the meal, shells were probably stored in the pit for further use.

Roman clay pits in the alluvial plain of NE Italy: from their ancient environmental impact to the geoarchaeology signature

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In European alluvial plains the present topography has been strongly modified by humans and the soil is often overprinted by different diachronic activities. Recent and modern land use generally reworked multiphase archaeological traces, hampering the possibility to reconstruct past landscapes and infer ancient environmental impact. In the distal portion of the Venetian-Friulian Plain remnants of semi-natural lowland forests are present and they have not been affected by agriculture after the Roman times (i.e., since around 500 CE).
Analysis of DEMs obtained by high-resolution LiDAR data (30 pts/m^2) reveals a complex palimpsest of subtle landforms underneath the woodlands. Elsewhere, in the areas which have been deforested and turned into croplands in recent times, topography is levelled but can be reconstructed through photointerpretation of satellite images and historic aerial pictures. Our investigations recognized six large Roman sites where clay was extracted for bricks and pottery production, leaving from tens to hundreds of square clay pits. These structures were 5-15 m in length and 1-2 m in depth and they let the groundwater table to crop out, but now are generally filled. The quarried areas exploited LGM alluvial clays, and in some cases, they are located where the occurrence of a Roman furnace was unknown. The largest settlement corresponds to the craft workshop of the kilns of Carlino Chiamana, which consists of more than 300 pits, covering an area of 20 hectares. The total extent of all the excavation sites covers about 50 hectares, underlining their profound impact on the landscape. Even today, in the plains of NE Italy, beside centuriation, ancient towns and roads, clay pits areas are among the most resilient archaeological traces. Some of the clay pits are still preserved as depressions underneath the woods, while others are filled and levelled. Stratigraphic investigation was carried out on some of the pits, revealing an infill of lacustrine sediments. These consist of gyttja and peat accumulation, that are promising paleo-environmental archives for the last 2000 years. Notwithstanding, clay pits areas are prone to rapid deterioration due to modern agriculture, thus their recognition as significant archaeological features urges some actions for their preservation.

Reconstructing landscapes through lithics. Raw material acquisition strategies and prehistoric mobility in Central Italy: new data from Grotta Battifratta (RI)

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Throughout Prehistory, humans have adapted to the natural environment shaping their coping strategies with the ecosystem. Tracing ancient movement is a key point to detect human interactions with the environment and adaptive mechanisms. Reconstructing past human routes means, indeed, to comprehend the ancient landscape as it was known and perceived and, consequently, its exploitation.
Here, we will discuss the role of lithic data in investigating territorial behavior. Lithics are potentially informative of various aspects of ancient groups as they played an essential role during Prehistory. Siliceous rocks were diffusely exploited to produce stone artifacts and humans developed different supplying strategies to acquire raw materials. Therefore, human groups were deeply aware of the ecosystem they lived in. As a result, characterization and provenance analyses offer an interpretative tool to archaeologists to investigate connectivity and human-environment relationships, revealing to what extent humans exploited the surrounding ecosystem. These theoretical criteria have been applied through a geoarchaeological approach to the investigation of the Sabina region (northern Latium, central Italy), whose raw material sources are still unknown. Non-destructive petrographic analyses have been run on the lithic assemblage of Grotta Battifratta (RI), a cave site showing a long-term occupation from the upper Pleistocene on. The Neolithic sample suggests the exploitation of different siliceous rocks, whose variability has been analyzed using different methods with the aim of identifying raw material sources. The identification of lithic outcrops and deposits will help defining site-catchment areas, linking the site to a larger territory in order to trace spatial mobility and reconstruct the ancient landscape exploited during the Neolithic peopling of the region.

Pottery and ancient landscape: provenience analysis of Battifratta Cave materials

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The relationship between nature and humans in the past is closely linked and complex. The reconstruction of the ancient landscape is essential to understanding human behaviour as the environment has always played a key role in shaping human choices. Integrated approaches to analysing the material culture can reveal further information to understand past environmental change and human choices. In recent years, archaeology has employed interdisciplinary methodologies following geoarchaeological approaches. These approaches significantly enhance the potential of research focused on reconstructing the landscape and the natural resources exploited. In this framework, characterisation analyses can reveal the origin of raw materials and technology. Studies on pottery and clay are strategic as they connect the ancient landscape to raw material sources, production areas and archaeological sites. A good example is Battifratta Cave, a prehistoric site of the Sabina region (northern Latium, Italy) containing Neolithic and Bronze Age pottery. Petrographic analyses in thin sections and FTIR analyses have been performed on archaeological and geological samples to detect the clay sources exploited during the Neolithic. Our ultimate goal is to understand the provenance of the clay used for ceramic production and to discuss prehistoric mobility in the Sabina region.

The sedimentary record of the oldest Roman artificial basin

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Portus, the maritime harbor of ancient Rome, is a complex port composed of basins and channels connecting the harbor to the city of Rome via the Tiber River. The still existing iconic hexagonal basin, built under the emperor Trajan (AD 110-112), hosts a unique sedimentary archive of man-environment interactions. Through multidisciplinary investigations involving dating methods, sedimentology, palynology, micropaleontology (ostracods, foraminifers and dinoflagellates) and paleomagnetism we analyzed the environmental changes of the last 3000 years in the area of Rome. We identified a lagoon pre-existing the port and a series of subsequent events starting with the excavation of the Trajan harbor and its opening both to the Tiber River and to the sea. We also characterized the water depth of the basin, the salinity changes, the landscape modifications and the history of the abandonment of the harbor. Anthropocene records are often a conundrum where natural and human forcings blend and are difficult to disentangle. Ancient harbors are precious archives of human-environment interaction. Dating harbor deposits and correlating their stratigraphy are major challenges because of potentially high sedimentation rates over short periods of time, possible dredging events, and location in marginal marine environments. Only the integration of direct and indirect dating methods with the information from historical documentation and the paleoenvironmental data has allowed to reconstruct the complex fluvio-deltaic sedimentary succession of the Trajan harbor where anthropic disturbance ruled for at least two millennia.

The role of pollen and non-pollen palynomorphs in the interpretation of the Neolithic site „Gorjani-Topole“ (Eastern Croatia)

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The main goal of our work is to understand the social dynamic in the late Neolithic Slavonia (Eastern Croatia) through computational simulations and the development of cultural and natural relations by using archaeological, biological, geological and sociological data. This multiproxy approach, which we implement through the MOPRENS project (https://croris.hr/projekti/projekt/4518?lang=en), should guarantee notable results in the interpretation of the natural and cultural basis of the „junction area“ between Central Europe and Balkan. Geobiological contribution to the project is primarily based on the palynomorphs analysis. However, pollen and plant spores used in the reconstruction or agricultural activities or the interpretation of vegetation changes are usually poorly preserved in archaeological terrestrial environments. In such circumstances non-pollen palynomorphs (NPPs) like fungal spores, algae cysts, amoeba, eggs of parasitic animals, etc. can be of significant importance. However, the limitations in the ecological interpretation of the NPPs, as well as the possibility of determining numerous different microfossils still represent an insurmountable challenge, but important strides have been made in recent decades. In this sense, the preliminary analysed samples from Slavonia, dominated by *Pseudoschizaea*, and accompanied by a low pollen richness, confirms the poor preservation conditions, as well as erosive processes caused by either drying or fires. Others samples, like those in which amoebae were noticed, complemented by the appearance of probably algae (eg. HdV-225, HdV-984, HdV-989), indicates wetter and more oligotrophic conditions. Simultaneously, better preservation conditions in some samples, marked by moisture indicators, result in a greater occurrence of pollen and plant spores. Such conditions contributed to the preservation of cereal pollen, among others, and *Epicoccum* fungi, which confirm agricultural activities of Neolithic communities. Although the preliminary analysed samples are poor in palynomorphs, and they don’t reach statistical minimum of 300 pollen grains, NPPs shed light on the hydrological regime (fungi vs. algae as indicators of moisture vs. drought), trophic state (eg. *Assulina muscorum*), erosion/desiccation (eg. HdV-200, UAB-7, UAB-48, *Pseudoschizaea*) or human influence (eg. HdV-351 and probably *Epicoccum*). By continuing this research, the pollen/NPPs spectrum will certainly improve our understanding of natural and human-induced changes during the Neolithic in the broader Danube area.

Reconstruction of Roman age land cover in Pannonia (Western Hungary) using pollen, anthracological, carpological and GIS studies

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The Romans conquered Pannonia (Western Hungary, EC Europe) between 13 and 8 BC. By the 2nd century the area around Lake Balaton had been romanized through settlements. We can reconstruct quantitatively how land cover has changed through the Roman age, and how arable grazed land enlarged by pollen analyis of large lake sediments, in this case our target is Lake Balaton, from where three 60-cm sediment cores were obtained from 2-4-6 km distance from tis northern shore. Dated by 210Pb, 127Cs and AMS 14C, two of theses sediment have been studied for pollen, macro and micro elemental changes and sedimentary chlorophyll. For the land cover reconstruction we used the LRA-Reveals (Landscape Reconstruction Algorithm) model, which estimates the true vegetation distribution from the pollen distribution, taking into account basin size, pollen productivity and fall-speed of the pollen types. These reconstructions are supplemented with the carpological and wood charcoal records of farm sites (Balatonlelle, Balatonfőkajár, 2-3rd century), a granary (Szabadbattyán, 4rd century) and the roman town Tác-Gorsium (2-5rd century). Plant remains come from various archaeological objects. Among the carpological findings, we found the largest number of cereals and we also observed traces of cultivation in the area around the settlements. In Balatonfőkajár, more than 90 % of the carpological finds were cereals, of which one percent were Triticum aestivum. At Szabadbattyán and Tác-Gorsium, 28 % of the more than 10,000 remains were Triticum aestivum, Secale cereale 10 %, and Hordeum vulgare 7 %. At the Balatonlelle site, the cereal species identified in the highest proportion was Panicum miliaceum, accounting for 31 % of the carpological finds. Based on our observations so far, oak-wood dominates the anthracological findings, which may show the effect of human selection. With our macro botanical study we determine the nature of the environment and land use of the sites, we also deal with the similarities and differences of the land use in Roman times. We process, evaluate and present the data with the ArcGIS GIS tool and software, generalized to different coverage categories.

Luminescence Chronology of reticulated laterite in humid subtropical mountains of South China

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Laterite is a red weathering crust developed with various rocks and Quaternary loose sediments as its parent material in the tropics and subtropics regions of the world, and it is also the most widely distributed Quaternary earthy accumulation in China. Since the 1930s, most researchers have believed that the fluvial reticulated laterite in southern China was influenced by the warm and humid climate of the Middle Pleistocene. In recent years, the remains of Paleolithic human activities are often found in the reticulated laterite of southern China. However, the study of laterite chronology is sporadic or there is no critical chronological analysis, which causes uncertainty in the identification and discussion of the ages of reticulated laterite and Paleolithic sites in South China. In this study, a paleolithic site found in fluvial reticulated laterite in South China was systematically tested by quartz optical luminescence dating and geomorphic process analysis. The results show that, (1) The T_3 terrace, an archive of hominin activity in the study area, primarily formed between 56 and 11 ka. (2) Reticulated laterite cannot be used simply to determine the ages of the Paleolithic sites found in this stratum, and typical reticulated laterite cannot be used as a marker for climatic stratigraphy and chronostratigraphy. The formation time of the reticulated laterite varied significantly between different sedimentary facies. The fluvial reticulated laterite in the southern tropics, under suitable hydrothermal conditions, can form within tens of thousands of years or even within 10 ka. (3) Human activities can affect the burial age of reticulated red soil, and the temporal nature of riverine terraces can also lead to an inversion in the age of reticulated red soil.

Late Pleistocene artists in caves: the figurative portable art of Grotta Romanelli (Southern Italy)

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With more than 200 decorated objects made on stone and bone, Romanelli Cave has one of the richest records of Palaeolithic portable art of Italy. However, this incredible heritage is only partially edited and the last systematic research work dates back to more than fifty years.

Thanks to the resumption of the investigation activities in the cave, new attention has been rekindled to the study of the portable art objects found in previous historical excavations and dispersed among several institutions in Italy, and the newly discovered engraved objects, which provide crucial information having a precise stratigraphic position.

The decorated objects reveal a variety of raw materials (stone and bone), and diversities in the represented themes (zoomorphic, geometric, anthropomorphic), and decorating techniques (scratching with different tools and or points, and painting). According to the reports from the old excavations, they were found in the uppermost stratigraphic units filling the cave (ISU5), containing Upper Palaeolithic lithic and bone tools, and numerous faunal remains, and recently dated between 13.6 cal ka BP and 11.4 cal ka BP.

At this stage of the research, we selected the rock fragments decorated with figurative themes (zoomorphic and anthropomorphic subjects), analysing: a) the style of the figures and their technological features to investigate changes over time; b) their stratigraphic setting and related chronology; c) the lithology and petrology of the raw material to understand its origin in terms of source-area and the post- or pre-burial weathering processes. The palaeontological analysis supplies further supporting data to identify the animal figures, giving possible connections between the environment surrounding the site and the graphic production. Finally, comparisons with Late Pleistocene portable and parietal art from other Mediterranean sites provide the essential information to propose potential cultural connections at large scale.

A new 270,000 year pollen and charcoal record reveals more than 40,000 years of human landscape modification in Tasmania, Australia

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The southwest Tasmanian "Wilderness" World Heritage Area is home to what is often considered an ecological paradox: the dominance by a flammable plant community in a cool and wet landscape that "should" host rainforest. This anomaly is understood as the product of burning by Palawa (Aboriginal Tasmanians), yet debate surround the longevity of landscape modification by Palawa people. Here, we explore a new 270,000 year archive of vegetation and fire changes in this region. The data demonstrates a radical landscape transformation immediately following the arrival of Palawa to Tasmania ca. 40,000 years ago. This talk will unpack this exceptional archive in the context of human influence on the earth system and how knowledge of the origin of contemporary landscapes is essential for sustainable management moving forward.

Rupestrian trail: activation of the economy through paleontology and archeology in the northern region of the Mato Grosso do Sul state (Brazil)

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This work aims creating social innovation and sustainable development through the bioeconomy. We seek to induce the citizens and tourists of Mato Grosso do Sul state in the learning of cultural processes and economic circulation, by using archaeological and paleontological remains. Starting from Heritage Education, teaching and learning can be streamlined and expanded far beyond the school environment. Including the community in this process will allow students and other members of the community to discover places, stories, objects, monuments and traditions that were or are important to their history. The paleontological, prehistoric and historical heritage and the environment in which it is inserted offer opportunities to arouse in students, teachers, civil servants, merchants and tour guides feelings of surprise and curiosity, leading them to learn about what a cultural and heritage asset is and to understand that popularizing this knowledge will generate income. From this route, products and services may be generated, strengthening the bioeconomy of the regions involved. In the study area, the paleontological Devonian sites and the archaeological data with up to 12,000 dates provide a unique experience. It is a return to the past, the reconstruction of our ancestors' daily lives and the historical and cultural knowledge provided by fossils (mainly bivalves and trilobites), artifacts, engravings and cave paintings that make archaeological tourism a different and surprising option for tourists. This type of tourist activity can promote contact with the culture of ancient peoples, which allows the tourist to be closer to the Past and provides means of livelihood through marketable generated products, knowledge and involvement of the local citizen. Other UFMS research will also compose this work to activate the bioeconomy, such as: the ceramic axis, whose ceramics are produced along with local cave paintings; the food axis; the chemical-pharmaceutical and botanical axis, that disseminate recipes with plants and fruits from the biomes of Cerrado and Pantanal, both for consumption and for products manufacture. Thus, joining research from different areas produced by UFMS intends to activate the economy of non-industrialized cities which are rich in paleontological fossils and archaeological sites.

Pre-Maori settlement in New Zealand: evidence from Lake Pupuke sediment record through fecal biomarkers and geochemical approach

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Archaeological records suggest that Maori arrived in New Zealand around 700 to 800 cal BP. Their settlement brought tremendous environment and landscape modifications in the island in place for their horticulture and pasture practices. However, Maori oral traditions imply otherwise; suggesting Iwis, different Maori tribes, could have arrived 3 to 4 generations earlier than expected.

In this study we present downcore fecal sterol coupled with XRF (Ti) and magnetic susceptibility data, TOC, $\delta^{15}N$ and $\delta^{13}C$, in Lake Pupuke, in the North Island of New Zealand spanning 1871 cal yr BP. Fecal sterols (5β-coprostanol + 5β-epicoprostanol) are found in human wastes and are widely used as tracers for prehistoric human presence. Ti and magnetic susceptibility data are used as proxy for terrigenous input and/or erosion. While TOC, $\delta^{15}N$ and $\delta^{13}C$ could be indicative of changes in carbon source.

Downcore coprostanol and epicoprostanol showed peaks at ~700 cal yr BP, which is known to be the Maori arrival. Interestingly, presence of coprostanol and epicoprostanol showed comparable peaks/concentrations at around ~1300 cal yr BP: 500 to 600 years before the known Maori arrival. TOC/CN indicate an overall decreasing trend from 1300 cal yr BP to present, indicative of increasing lake productivity. Magnetic susceptibility and Ti data were constant from 1800 up 700 cal yr BP. Its trend only started to increase just after the coprostanol and epicoprostanol peaks around 700 cal yr BP.

The fecal markers peaking at around 1300 cal yr BP could imply early human presence in the area in concurrence to Maori oral traditions. Geochemical data observed in the sediment record indicate different signals in comparison to the pre and known Maori fecal sterol peaks, proposing that the Iwis arrived in the area could have different approaches in terms of landscape and environment modifications.

Human-environment interactions in Central Queensland from the Pleistocene to the Holocene

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The palaeoenvironments of Australia have changed considerably through the Pleistocene and Holocene. Indigenous Australians not only adapted to these changes, but have in turn modified and managed their environment to maintain ecosystems and enhance their subsistence economies. Detailed palaeoenvironmental records are vital for understanding this relationship, but in many regions of Australia such records are currently lacking. This paper presents a new 50,000 year record from Abercorn Springs in Central Queensland. The 5 m-deep core provides the oldest palaeoenvironmental record for the region and fills a critical gap between eastern Australia's tropical north and temperate south, which have been much more extensively studied. Using a multi-proxy approach including pollen, phytoliths, charcoal, and XRF analyses, this presentation explores the relationships between humans, fire, and the environment. Several charcoal peaks throughout the core appear to demonstrate continued human interactions with the landscape, with fire being used to create a more open environment and maintain grasslands, starting from c. 40,000 BP. An extended dry period appears to match with propositions of an extended Last Glacial Maximum (LGM), dating to c. 30,000 BP. Post-LGM, the site continues an overall drying trend, transitioning from a lake to a wetland. Environmental variability is high throughout, with broad trends including a decrease in Restionaceae and *Casuarina*, an increase in pteridophytes, Poaceae, and Myrtaceae, and a constant presence of Asteraceae. There is a marked difference in the record post European contact, likely due to the cessation of Indigenous fire management, the introduction of grazing animals, and the extraction of water from the spring. Not only does this site provide an environmental framework in which to situate the regional archaeological record, but it also demonstrates human agency on the environment and how this relationship has changed through time including through drastic changes in climate such as the LGM.

Vegetation shifts in the rain forest of Central Africa during the Pleistocene-Holocene transition period: preliminary pollen and isotopic evidences from Lake Nguengue, Central African Republic.

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Tropical rain forests are generally crucial for conservation of biodiversity and earth's biogeochemical cycles. Forest loss due to anthropogenic activities and/or global warming, is undoubtedly a common source of economic, societal and environmental disasters, hence protection of rainforest and its resources, is very critical to mankind. There is also need to understand dynamics of rainforest responses to environmental changes in order to examine their vulnerability and resilience. However, forest dynamics are often gradual and complex processes, hence they are difficult to understand based on only short-term experiments. There is yet a rarity in the availability of continuous records before the beginning of a notable Holocene anthropic influence in Central African lowlands. To provide data over long timescales, this research study aimed at reconstructing vegetation in response to past climatic change in the last 20,000 years in Central African Republic. In the current study, we collected sub-sediment samples from a core at Lake Nguengue, situated towards the northern edge of the Central Africa Republic forest. Pollen, charcoal and isotopic records provided preliminary data, revealing vegetation shifts during the Pleistocene-Holocene transition. From ca. 20,000 years ago in the Pleistocene, there was a persistent establishment of a dry savanna grassland, although it fluctuated in its extent. This continued until 12,000 years ago when rainforest started appearing gradually and climate became relatively more humid, contemporaneous of the African Humid Period. Forest later reached its peak during the Holocene within a typically wet condition and dominated. Although it still dominated the landscape, even after the African Humid Period (5,000 years ago), some fluctuations in the extent of forest, seems to have occurred from the mid- to late Holocene. Based on charcoal analyses, human impact is visible only from the last millennium and it seems to have begun at a later period when compared to other study sites in the region. These outcomes consequently justify that the low elevation study site, is a reliable locus in understanding the dynamics of rain forest responses to past climate change during the mid- to late Holocene transition.

Intensification of rice farming and its environmental consequences recorded in a Liangzhu reservoir, China

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The origin and subsequent development of rice agriculture enabled humans to transition from hunter-gatherers to farmers, thereby profoundly changing human society. However, less attention is focused on when and how rice cultivation practices began to alter the landscape. In this study, sediment from the reservoir inside the Mifenglong dam, Liangzhu hydraulic system was sampled. Accelerator mass spectrometry (AMS) radiocarbon dating and optically stimulated luminescence (OSL) dating results revealed that the duration of the Mifenglong reservoir ranged from 4,900 cal BP to 1,500 cal BP. The results showed that between 2,500 cal BP and 1,500 cal BP, intensive rice farming practices transformed the surrounding vegetation and landscapes through deforestation and changes in herbaceous plant structure. This study provides an insight into the impact of human activities and how they influenced the environment on a local scale, as well as contributing to a deeper understanding of the relationships between agricultural development and landscape changes.

Impact of modern-day landscape activities on the Palaeolithic record of central Narmada Valley, Madhya Pradesh (India)

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In the past, different hominin populations targeted diverse rock types (e.g., quartzite, basalt, limestone, flint) to produce lithic artefacts throughout the prehistoric period. The choice in procurement was based on a range of attributes, including manufacturing potential, technological requirements, intended activity, strength, durability, availability, etc. In the present day, construction is an unavoidable part of development, which is reflected in the expansion of human settlements, giving rise to enhanced mining and quarrying activities for the recovery of various rocks as basic raw materials. Numerous archaeological discoveries have been made across the globe as a result of various extraction and/or construction ventures. Similar trends can also be noted in different regions in the central Narmada Valley, Madhya Pradesh. The present research shows how mining activities within the Narmada floodplain and foothills of the Vindhyan Range have resulted in the exposure of new Palaeolithic deposits. It demonstrates how modern landscape modifications to both surface and sub-subsurface deposits need our constant attention to make sure that appropriate recording of archaeological remains is conducted. This research also illustrates how mining and construction in the central Narmada Valley impact the Palaeolithic record in both positive and negative ways.

Natural environmental change and its impact on early Late Paleolithic people in the northeast central Korean Peninsula during MIS 3 (40–30 cal ka)

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We comprehensively analyzed sediments obtained from an archaeological excavation. A trench sediment profile of Maedun Cave, South Korea, was analyzed geoarchaeologically. Multi-proxy analyses (palynomorphs, grain size, magnetic susceptibility, animal bones, and artifacts) reflected the vegetation, hydroclimate, and lives of prehistoric people at MIS 3 (ca. 40–30 cal ka) in the early Late Paleolithic. The palynoflora consisted of pollen and non-pollen palynomorphs. Under the air-circulation system in the cave, anemophilous pollen flowed in during the day, whereas water-borne pollen and spores, and freshwater algae, were transported by flooding during the summer monsoon rainy season. Mixed conifer and deciduous broad-leaved forest with an understory of pteridophytes flourished around the northeast central Korean Peninsula during MIS 3. Freshwater algae and grass pollen records may reflect precipitation intensity. It is assumed that they had flowed in during flooding caused by high precipitation during the enhanced East Asian summer monsoon, corresponding to Dansgaard–Oeschger events 5 and 8 of $\delta^{18}O$ GISP2 and Hulu Cave. The prehistoric people hunted herbivorous animals in the area around Maedun Cave and sheltered inside it seasonally. They also used the grains of oats growing near the dwelling as a source of food.

New luminescence dates from Middle Stone Age of Bargny 3 site (Senegal) and its implications for the human occupations in West Africa

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The Middle Stone Age (MSA) is the major chrono-cultural phase associated with *Homo sapiens* emergence and evolution in Africa. In South and North Africa, the MSA sites mostly associated with evidence of exploitation of marine resources and advanced cognitive hallmarks are located in coastal area. These sites are questioning the importance of coastal zone as probable corridors for human expansion throughout the African continent. However, due to the scarcity of chronological data, the question of MSA human occupation in the West Africa coast has not been studied in depth. Over the last decade, some archaeological surveys have uncovered a few coastal MSA sites. The Bargny quarries are known since the 40's and were considered complex surface sites. Archaeological surveys led in 2018 and 2021 allowed to discover *in situ* sequence of Bargny 3 (BG3) located in the coastal village of Bargny (Senegal). The archaeological sequence consists of 5 sedimentary horizons. The lower unit, characterized by orange silty sand, is associated with more than 1800 lithics artefacts made from chert: their preliminary technological study reveals classic MSA technologies, including Levallois, discoidal cores associated with a large number of flakes rarely retouched. The archaeological artefacts and evidence of human occupations are absent from the following two units. Then, the uppermost two units attest to the protohistoric presence in this area.

The six samples collected from the BG3 site were dated using the Optically Stimulated Luminescence following the single aliquot regenerative dose (SAR) protocol at CENIEH. Samples were measured on 2 mm multigrain quartz aliquots. Our preliminary OSL ages from the lowest unit demonstrate for the first time the presence of an MSA in coastal West Africa during the MIS 5 and its contemporaneity with the age of the Ravin Blanc I, the oldest MSA site known until today in West Africa. From a multi-method chronological perspective, Electron Spin Resonance (ESR) dating of optically quartz grains is planned for the MSA unit of BG3.

Soil carbonate U-Th ages from the stone tool-bearing PC5 paleosol of the Lakhuti loess section, Tajikistan

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Migration routes through Central Asia (CA) were key to the expansion of humans from Africa to Asia. Indeed, stone tools are often found in the thick wind-blown dust (loess) deposits and interbedded paleosols, particularly in Tajikistan. These dust deposits can be tens of meters thick and have accumulated continuously over the last 2-3 million years. Large numbers of stone tools are found in some of the ancient soil layers. These generally represent warmer, wetter interglacial periods that were more favourable for human occupation. To understand the history of human activity recorded in these deposits we need to know exactly when the sediment was deposited, and what the past climate and environment was like. As such, here we present the first results of U-Th dating of a soil carbonate from the stone tool-bearing PC5 paleosol at the Lakhuti archeological site, which has previously been correlated with Marine Isotope Stage (MIS) 13. The dated, uniquely whitish-coloured soil nodule was recovered from the PC5 soil at a depth of 1.05 m (from upper paleosol boundary) in October 2021 during a field campaign of the THOCA project (www.thoca.org). The half-cut soil carbonate showed a compact, micritic internal structure with relatively low detrital contamination. Geochemical analyses revealed high ^{238}U (55.8-60.6 ppm) and relatively low ^{232}Th concentrations (0.42-0.44 ppm) in this secondary carbonate, making it an ideal target for U-Th age determination. The corrected $^{230}Th/^{234}U$ ages of the soil carbonate are 349,611±9549 and 369,684±10493 years, close to the MIS 11/10 boundary. These preliminary data suggest that PC5 soil formation and human activity in the region may be related to the MIS 11 interglacial period, roughly 400 thousands years ago, rather than MIS 13.

Establishing a robust chronology for faunal and human evolution in the middle Atbara Valley, Sudan

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Fluvial sediments of the middle Atbara River, one of the major tributaries of the Nile, in eastern Sudan contain abundant vertebrate fossils and stone tools. From our field investigations between 2018 and 2022, fossils of over 700 specimens, including hominins attributable to Middle Pleistocene Homo, and Acheulean lithic assemblages have been found in the Butana Bridge Synthem (BBS) and the Khashm El Girba Synthem (KGS) in four areas – Al Sharafa, Al Shahateb, Tomat, and Wad Hedi stretching ~100 km along the Atbara River valley. In order to correlate the fluvial strata at these different locations and to establish a robust chronology of the fossil and lithic assemblages, high density optically stimulated luminescence (OSL) dating of sediments as well as radiocarbon and ^{230}Th/U dating of shells and bones were conducted. Both quartz and feldspar minerals were used for OSL dating. For feldspar OSL, the pulsed IR stimulation at low temperatures was adopted to make use of good bleachability and stability of the signal. Furthermore, stringent quality-check criteria were introduced for screening radiocarbon and ^{230}Th/U ages. After the screening, the ages obtained from different dating methods were consistent, and revealed a quasi-continuous aggradation of the fluvial sediments between ~250 and ~15 ka. The sediments with in-situ Acheulean stone tools were dated to ~220-140 ka, indicating the later persistence of Early Stone Age in the Middle Atbara area, compared to the other parts of Africa.

The last 1 Ma record from the fluvial terraces system of the River Somme Valley (Northern France) and the background of the earliest Acheulean occupation of Northwestern Europe

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Following the discovery at the end of the 19th century of the famous Palaeolithic sites of Abbeville "Moulin-Quignon" and Amiens "Saint-Acheul" (type-site of the Acheulean), the River Somme valley has been for a long time recognized as the "cradle of Prehistory" in Europe. It is also the place where the first approach combining geology and prehistory, known as "archaeogeology", was conceptualised by Boucher de Perthes (1850). Modern research or "geoarchaeology", combining geology, geomorphology, sedimentology, pedology, palaeontology and archaeology was later developed in the valley, especially during the pioneering works by Bourdier in the 1970s. During the last 30 years, the study of the Quaternary sequences of the Somme basin, coupled with the development of absolute dating methods (ESR on fluvial quartz, ESR/U-series on large mammal teeth, TIMS U-series on calcareous tufa, OSL on sediment and TL on heated flints), has made the Somme terrace system an international reference for both Pleistocene geology and archaeology. It is presently one of the best locations in Europe for the evidencing of the response of river systems to glacial-interglacial climatic cycles during the last Ma. This system, fully incised in the Cretaceous bedrock, is made up of 10 stepped alluvial formations spread over 55 m of relative altitude. The resulting fluvial staircase is covered by thick slope deposits (loess-palaeosol sequences up to 8 m thick), the complexity of which increases with the age of the underlying fluvial sequence. Researches are completed by investigations undertaken on the present valley infilling in which systematic radiocarbon dating allows an accurate correlation between the various units of the morpho-sedimentary sequence and climatic events during the last Glacial-Interglacial cycle. Recent discoveries such as the Gravettian site of Amiens-Renancourt (2013) or the rediscovery of the emblematic Acheulean site of Abbeville Moulin Quignon now dated ca 670 ka (2016) have reinforced the importance of the Somme valley in current researches. This work is thus a fundamental and still evolving contribution to the study of the relationship between Europe's earliest human settlements and climatic and environmental variations and new investigations are planned for 2023 in the frame of the "Lateurope" ERC project.

Multi-method dating reveals 200 ka of Middle Palaeolithic occupation at Maras rock shelter, Rhone Valley, France

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The Maras rock shelter ("Abri du Maras"), located on the right bank of Middle Rhone River in France, displays a long stratigraphic sequence attributed to Neanderthals. The site is characterised by an exceptional preservation of archaeological remains, including bones that can be dated using radiocarbon (^{14}C) and teeth using electron spin resonance combined with uranium series (ESR/U-series). The sedimentary matrix contains quartz, whose age can be determined using optically stimulated luminescence (OSL) dating.
By combining these dating methods and comparing our data with previous ESR/U-series on teeth, U-series on bones and soda straws, and infrared stimulated luminescence on feldspar, we were able to clarify the occupation time of the rock shelter during the Middle Palaeolithic, for a period spanning over 200,000 years.
Age results for the base of the sequence (layer 6) show that Neanderthal occupation dates back to marine isotopic stage (MIS) 7, between 247 ± 34 and 233 ± 33 ka, and that the site was repeatedly occupied during MIS 5 (layer 5, 127 ± 17 – 90 ± 9 ka) and 3 (up to 39,280 years cal BP).
Our study provides new insights into the timing of the evolution of Neanderthal behaviour at the Maras rock shelter, which seems to have been used as a long-term residency by Neanderthals, specifically during inter-glacial periods, between around 250 and 40 ka.

Chronostratigraphic framework of the Upper Palaeolithic levels from the archaeological site of La Malia rock shelter (Guadalajara, Spain)

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La Malia rock shelter contains a Pleistocene to Holocene sedimentary infill in which at least 3 Upper Palaeolithic levels have been identified based on their composition, texture, colour, sedimentary structures, and archaeological content. A combination of Electron Spin Resonance (ESR) dating of fossil teeth and Optically Stimulated Luminescence (OSL) dating of quartz grains was employed to chronologically constraint the Upper Palaeolithic occupations. For this purpose, several fossil and sediment samples were collected. Preliminary ages yield a consistent Late Pleistocene chronology and roughly correlate these levels to Marine Isotope Stages (MIS) 2-3. These results demonstrate the presence of *Homo sapiens* in inland Iberia during the early Upper Palaeolithic, which adds a new dimension to what we currently know about the mobility and occupation dynamics of our species during this period.

People – Platforms – Palaeolakes. Preliminary results of a palynological analysis from a Lateglacial-Early Holocene lake-site in northern Denmark

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A new Lateglacial – Early Holocene site close to Pårup (Sjælland, Denmark) was investigated by the Museum-Nordsjælland revealing lithic assemblages of both, Palaeolithic and Mesolithic typologies.
The location in a former shore-line of lake Søborg featured excellent preservation conditions for organic material. Among these were two wooden platforms made of *Populus tremula* that formerly reached out into the lake and have been dated to the early Preboreal.
A near-site sediment core has recently been taken by the National Museum of Denmark and the objective of a preliminary palynological investigation was to study changes in the local vegetation across the Pleistocene-Holocene boundary.
The find situation, including the wooden platforms, is strongly reminiscent of the Star Carr site (UK). Therefore, we additionally ask whether human action and patterns in shore-line usage can be traced by looking at charcoal particles as well as alterations in the shoreline vegetation (e.g. *Phragmites*).

U/Th dating of Neanderthal-bearing hyena den bone accumulation at Grotta Guattari (Central Italy)

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The Tyrrhenian coast of Italy preserves an important number of open-air, rocky shelter and caves with Middle Palaeolithic archaeological succession (Musterian). Despite the abundance of archaeological and archeozoological remains found in many of these caves, the associated finding of Middle Palaeolithic human remains is extremely rare. An extraordinary exception is the “Grotta Guattari”, the investigation of which started in 1939 after the fortuitous discovery of a masterfully preserved Neanderthal skull later known as Circeo I.
In the October 2019 a new excavation campaign was initiated in the inner part of the cave, which was untouched by previous excavation. The new excavation brought to light a considerable number of new human remains as part of a considerable large mammal bone accumulation by hyena. The finding occur in shallow (c. 30 cm) layer of sandy sediments including several levels of speleothems deposition, which allowed to dating with high precision of the cave occupation by hyenas and their bone accumulation, human ones included. Specifically, several U/Th dating consistently indicate a very short period of deposition during marine isotope stage 4 at ca. 65-66 ka. In agreement with this chronology, the top of the archaeological succession of the inner part of the cave, marked by pop-corn-like concretion covering, is dated at ca. 58 ka, which represents a *terminus ante quem* for the abandonment of the cave and its definitive closure until its discovery in 1939.

A new dating advance in archaeology: cosmogenic burial dating with P-PINI at Korolevo I

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Terrestrial cosmogenic nuclides have been applied widely as a chronometer in the geosciences and archaeology. Unlike more conventional dating methods, such as luminescence or radiocarbon dating, burial dating with cosmogenic nuclides can access the past few million years of early hominin dispersal. Here, we constrain the age of the lowermost cultural layer at Korolevo I (western Ukraine) by applying a burial dating method that combines cosmogenic beryllium-10 and aluminium-26 measurements with an inversion model known as P-PINI (Particle Pathway Inversion of Nuclide Inventories). P-PINI merges the cosmogenic nuclide production equations with a Monte Carlo method to simulate millions of samples describing all plausible erosion and burial histories, which are then compared to nuclide abundances measured in field samples to determine the most probable burial age. P-PINI has been applied previously in a geomorphological context; here, it is used in archaeology for the first time alongside the conventional isochron burial dating method and we evaluate the pros and cons of each.

On-site and off-site archives: chronological coupling of the Montmaurin multi-level cave system with landscape evolution of the Lannemezan megafan (SW France)

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The Montmaurin multi-level cave system is located in the French Pyrenean foreland. It has become famous since 1949 when archaeological excavations unearthed a human mandible attributed to *Homo heidelbergensis* (i.e. one of the few European specimens retrieved so far). A new research program starting in 2020 aims to study chronologically constrain sedimentary infills of this multi-level cave system, mostly focusing on the Coupe-Gorge cave and its 7m-thick sequence which bears human remains, such as a well-preserved humerus discovered in Summer 2022. The field campaign and analyses carried out over the last three years included high-resolution topographic measurements (laser), Uranium/Thorium dating of flowstone, clay mineralogy and fauna characterisation. However, understanding the caves' sedimentary infills requires an integration into landscape evolution at a broader spatial scale.

Against this background, this new project aims to establish a link at different spatial scales between human occupation at Montmaurin and the geomorphological evolution of the surrounding valleys incised into the Lannemezan megafan. Integrating both subaerial and underground markers, it accordingly focuses on reconstructing (1) the terrace staircase of fluvial valleys around the Montmaurin caves, i.e. Seygouade and Save Rivers, (2) the evolution of karstic networks over time in response to base-level variations, and (3) the caves' sedimentary history, including origin of material, filling phases, as well as post-depositional lateral and vertical movements. This project is based on a multidisciplinary approach which usefully combines complementary methods. The latter include geomorphological mapping, sedimentological analyses (i.e. granulometry, micromorphology, clay mineralogy, magnetic susceptibility), source tracking (i.e. SMIR,), and relative (i.e. portable luminescence reader, weathering rind analysis) as well as numerical (OSL, cosmogenic nuclides) dating. Expected results will bring new insights into the fluvial landscape evolution, i.e. phases of base-level stability and incision, as well as into sediment movements within the karstic network and between the cave's occupation phases. It will ultimately provide a better timeframe for the presence of *Homo heidelbergensis* at Montmaurin.

The impact of climatic changes on human occupation patterns during the Late Glacial recolonization of NW Belgium: an interdisciplinary assessment of Late Glacial sites in the Scheldt valley

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During the Late Glacial recolonization of NW Europe, hunter-gatherers preferably settled in sheltered environments and along river valleys and lake edges. However, few hunter-gatherer sites are known in the Scheldt basin of NW Belgium. It is at present not clear whether this scarcity is related to specific taphonomic factors and/or corresponds to a prehistoric reality. Moreover, the few known sites in the floodplains of the Scheldt and its tributaries all seem to date to the Younger Dryas (final stage of the Late Glacial, GS-1, 12.8–11.7 ka cal BP), which recently led to the hypothesis of a possible population shift from the inland lakes towards the riverbanks at the abrupt climatic transition from the overall warm AllerØd (GI-1a-c, 13.9–12.8 ka cal BP) to the extreme cold Younger Dryas (GS-1, 12.8–11.7 ka cal BP). We investigate this hypothesis through intensive geoarchaeological research of inland dunes in NW Belgium, as they represent dry elevations bordering late glacial floodplains, making them attractive spots for human occupation.

Since the age and triggers of inland dune formation in this area were still poorly understood, a first step in this research was to establish a dune accumulation chronology using quartz-based optically stimulated luminescence (OSL) dating and, if possible, radiocarbon dating. A total of nine dunes spread along the Scheldt basin were extensively dated. The resulting ages show that dune formation already started at the beginning of the late glacial (GI-1) and was not limited to the final cold Younger Dryas. Probably, periods of reduced vegetation related to climate deterioration (short, abrupt cooling events) and/or wildfires have stimulated aeolian activity in the previous stages of the Late Glacial. The late glacial age of the dunes further testifies to their potential as occupation spots for hunter-gatherers in that time. Consequently, systematic archaeological coring surveys have been performed on a selection of these dunes to detect sealed Late Glacial sites. The results indicate a decrease in sites during the Younger Dryas, which helps us to obtain a better understanding of the hunter-gatherer responses to the changing environment and climate in NW Belgium during the Late Glacial.

Volcanic ash (tephra) layers to synchronise archaeological and climate records in NW Africa

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Archaeological sites in NW Africa are rich in human fossils and artefacts, emerging at the forefront of evolutionary studies. However, these records do not have a precise chronology, preventing assessments of the drivers of cultural/behavioural transitions. Investigations reveal numerous volcanic ash (tephra) layers are interbedded within the Palaeolithic sequences and are likely to have originated from large volcanic eruptions in the Atlantic (e.g., Azores, Canary Islands, Cape Verde). Critically, the same ash layers will be preserved in offshore marine records situated downwind of these volcanoes, meaning they can be used as time-stratigraphic markers to synchronise the archaeological and paleoenvironmental records in this region for the first time. Here we outline the initial investigations into the eruptive history of the source volcanoes and discuss diagnostic glass compositions essential for correlating the tephra layers. Moreover, we present the detailed tephrostratigraphic record preserved in the nearby marine cores (including ODP 958), which has been established using density separation techniques. The sediments contain numerous non-visible (cryptotephra) layers and the volcanic glasses have been geochemically fingerprinted to correlate them to their eruption source. The marine tephrostratigraphy provides a new record of explosive eruptions dispersed to NW Africa over the last ~300 ka, and highlights ash layers that are likely to be in the archaeological sequences. The tephrostratigraphy from the ODP 958 core will provide both relative and absolute age-constraints (via Argon ages of the eruptions) for plant wax and other biomarker analysis, that will be used to generate regional vegetation, fire, and hydroclimate records of the habitats of early humans. This work provides the first steps in establishing a tephrostratigraphic framework for NW Africa and offers new possibilities for comparing climatic and cultural transitions during the Palaeolithic.

Middle Pleistocene Acheulean industrial complex in the last middle terrace of the Lower Guadalquivir (Southern Spain)

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The fluvial terraces of the Guadalquivir River in the Carmona-Sevilla sector preserve a series of alluvial deposits with Acheulean industry that represent the earliest Acheulean presence in the Guadalquivir basin (southern Spain). In a sequence of ten fluvial terraces identified in the sector (T5 to T14), the earliest solitary Acheulean remains have been found in fluvial deposits of the upper terraces (T7 and T8 from the Lower Pleistocene, ca. 800 ka) but without associated fauna. These remains are especially concentrated in the last middle terrace, referred to as “Las Jarillas” terrace (T12 at +29-35 m above the riverbed). Here, three successive lithostratigraphic units have been identified with overlying gravels and sands (USLC-1, 2 and 3) containing numerous lithic artifacts grouped in three sets with bifacial forms (CAB-1, 2, 3). The most common raw material is quartzite and light debitage (R1). In CAB-1 (>580 pieces), these industries are characterized by the presence of bifaces, handaxes, cleavers and trihedral picks realized in rocks of medium and large size (>10 cm). Of the three sets of lithic industries identified, the two lower ones (CAB-1 and 2) are associated with *Elephas* (*Palaeoloxodon*) *antiquus*, *Hippopotamus sp.*, *Equus ferus* and Bovidae, and have been dated to about ca. >220 and 400 ka (quarts-OSL and K-feldspar post-IRIR). This is an archaeological site that, through the study of the lithic industry, stratigraphically documents the successive phases of a full Acheulean between the MIS 11 climatic optimum and the end of the Middle Pleistocene (MIS 6).

Pleistocene human occupation of eastern Australia: new excavations at Minjerribah (North Stradbroke Island)

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Two new excavations in a large sand barrier island of Moreton Bay provide clear evidence for human occupation of eastern Australia during MIS3. Luminescence and radiocarbon dating indicate deposition of 6 m sandy sediments over ~150 ka on the downwind flank of a Pleistocene transgressive and parabolic dunefield. The modelled chronology for human settlement was tuned using the chronological model BayLum, including radiocarbon ages together with single-grain OSL ages on quartz. Together this indicates an age of at least 40-45 ka for initial occupation. At this time, the sand island was connected to the mainland across the broad floodplain of the Brisbane River. Sea level had been falling from -60 to -65 m and was still 10 km from the present coastline. Evidence of occupation comes from lithic artefacts, molluscs and limited vertebrate fauna. Over 1300 artefacts were recovered at one site. Tools were constructed from quartz, silcrete, chert, rhyolite and greenstone from extra- regional and local source materials. The changing lithologies may reflect changing territories, trade, and access to stone as the coastline retreated 25 km from the present shoreline at the LGM, and subsequently rose to +1 m, flooding the connection with the mainland by 8 ka. The faunal record shows that various species of adult molluscs are abundant at the site from 6.8 ka until 0.14 ka. The recalibrated ecological record from the nearby Native Companion Lagoon shows peaks in charcoal between 45 and 40 ka that may reflect the introduction of regular anthropogenic burning. Subsequent peaks in charcoal occur at 35 ka, 24 to 20 ka, 14 ka, 12 ka and from 5 ka to the present. Rainforest declined sharply after 20 ka, which may be owing to a more arid LGM climate and the increased continentality of the site. Its persistent absence during the Holocene may have an anthropogenic explanation. Australia's large sand islands are revealed to contain a rich archaeological record of land use and management during a period of major climate variability set against a background of rapid, extreme fluctuations in sea-level.

Exploring the legacy of past land use and cultural burning in Southeastern Australia.

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During the *Black Summer* of 2019-20, southeastern Australia experienced the worst fire season in recorded history. Unprecedented areas of forest burned resulting in catastrophic losses to life, property, and wildlife. In the aftermath of these fires, Indigenous cultural burning has been proposed as a potential management tool to mitigate these extreme bushfires. Following decades of fire-suppression associated with the British Invasion, an Indigenous-style "frequent cool-burn" fire regime has been proposed to help reduce landscape-scale fuel loads and decrease the incidence of extreme bushfires. While based on enormous reservoirs of traditional fire knowledge in Indigenous communities, this assertion needs empirical testing. To address this issue, we analyzed a 1000-year sedimentary charcoal record from Elusive Lake (EL), Victoria (37°44'50.91"S, 149°27'9.58"E) spanning the period of Indigenous cultural burning to British fire suppression. Charcoal data was analyzed using CHAR Analysis to reconstruct fire frequency and fire severity. Fourier Transformed Infrared Spectroscopy (FTIR) of charcoal chemistry was used to reconstruct low (200-300°C), mid (400-500) and high (600-700) temperature fires, as a proxy for maximum combustion temperatures. Preliminary CHAR and FTIR data indicate frequent low-severity and low-mid temperature fires between 1000 to 650 cal yr BP. Fire activity decreased between 650 to 100 cal yr BP indicated by low charcoal concentrations combined with more low-temperature charcoal. In the last century the largest charcoal influx and peak magnitude values in the last 1000 years accompanied by increased high-temperature charcoals suggesting fire severity increased during this period. When contextualized with the regional archaeological data, these data suggest that the fire regime prior to the British Invasion, was characterized by frequent, cool-burn fires, similar to those that characterize Aboriginal cultural burning practices. Following the British Invasion and implementation of fire suppression practices, fires became less frequent, larger, and more severe as a result of the combined factors of warming temperatures and fuel accumulation. Together these data provide a millennial-scale context of the influence of human-mediated fire regimes that can be used to inform modern fire mitigation and management efforts in southeastern Australia.

The battlefield of El Alamein as case study of environmental changes in Quaternary terrains of the Western Desert from WW2 to present urban explosion.

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In 1942, between July and the beginning of November, a series of battles and war actions took place in the Egyptian Desert (namely, Western Desert), near the location known as El Alamein.

The study is devoted to the geological-historical analysis of the environmental impact generated by the development of military operations, including the presence for 60 years of extensive minefields. At the end of the last century, oil prospecting led to the de-mining of the desert area, while on the coast a rising impact due to quarrying of limestones and sandstones and a huge coastal belt of new touristic resorts and facilities deeply changed the littoral. Now the inner part of the battlefield is the site of a large oilfield being extracted by dozens of pumps, while the Mediterranean side will be interested in the growth of the New El Alamein City, a brand-new three-million inhabitants' metropolis.

Desert quaternary geology and geomorphology have both influenced and been impacted by WW2 military operations and post-war oil extraction, quarry extraction, touristic over-exploitation, agri-business and recent urban development.

Artisanal Silk Heritage of West Bengal, India: A story of Colonialism, Globalization and Revival

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West Bengal is a state in the eastern side of India. It was known as the Bengal Presidency which consisted of both West Bengal and Bangladesh. Bengal was famous for its silk production and silk weaving since ancient times. Silk was one of the main textile industries of India which dates back to 2500 BCE. The silk industry in Bengal flourished due to the premium quality of 'Tussar' silk grown in this region and the high skills of native artisans. During the Mughal rule (1526-1761) silk industry in Bengal flourished, attracting many investors from different regions. Weavers from different zones of India were dependent on the silk yarn from Bengal. Bengal was accessible through land and sea routes. Most of the European nations entered India through Bengal and all were drawn to the local silk industry. Silk products were considered highly valued and luxurious items to export to Europe. After the Industrial revolution, Bengal silk became the raw material for European textile industries and India became the biggest market for European finished products. The policy of de-industrialization in India by the British Government, increased land revenue, highly imposed taxes, mismanagement of land, famine, and drought completely ruined the local silk industry. India earned its Independence in 1947 with the cost of partition. Bengal was divided into West Bengal and East Pakistan (now Bangladesh). Many farmers and weavers moved to Bangladesh. After, independence the main focus of India relied on the production of food grains. However, within a few decades, sericulture improved, and the silk industry gradually developed and became one of the leading cottage industries. However, after globalization, the silk industry faced a new problem of fast fashion. Traditional weavers produce traditional wear and are not equipped to follow international fashion trends. Due to India's own clothing heritage, the silk industry survived. The government is also promoting silk as a part of geo-heritage tourism and branding local silk products. In this paper, we will discuss the history, tradition, and policies related to the silk industry before and after colonial rule and the initiatives taken in contemporary times for its revival.

Understanding raw material variability in early percussive tools: exploring the Acheulean of Melka Wakena through laboratory mechanical experiments

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The evolution of human behaviour is marked by key human decision-making processes linked to the origins of technological variability in the early archaeological record. Investigating the nature and character of such variability is fundamental to access those past human dynamics.
Characterizing lithic tool raw materials with regard to their physical properties is crucial for exploring transformations in human behaviour through time and space. Raw material properties are known to influence artifact functional suitability and efficiency. Such properties have a major impact on the formation of diagnostic use-wear traces, which are necessary for the archaeological recognition and interpretation of artifact functions.
In this study we explore the use of percussive tools from the Acheulian assemblages of Melka Wakena (MW), a site-complex on the Ethiopian highlands that is dated 1.6 Ma to <0.7 Ma. The relatively high frequencies of well preserved, non-knapped tools at the MW assemblages provide an opportunity to explore the potential selection process and the use of this type of materials.
Our approach combines multi-scale, high-resolution analyses with a dedicated experimental program that seeks to differentiate wear formation processes in the raw materials identified at the site. This program includes mechanized controlled experiments to establish high variable control and record multiple variables. This was designed to automatically produce impact motions on the various raw material sampled in the site's area. Here we present the results of the first stage of the experimental project, with a focus on bone as the worked material. All samples are analysed using multi-scale 3D technology to map and quantitatively analyse surface alterations. The generated data will be a significant asset to support the analyses and interpretation of the archaeological tools.

Settlement Patterns of Early Hominids during the Early- Mid Pleistocene Period: A case study of Kanapoi site, West of Lake Turkana.

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How humans differ from other animals is central to many anthropological investigations. Such differences have not only been reported through the ESA– MSA transition but also through the emergence of anatomically modern humans. For decades, Scholars have proven that, unlike animals, our ancestors choose different solutions when faced with many problems in partnered ways. Archaeological assemblages from Kanapoi associated with both ESA and MSA lithic industries might reflect the different ways through which toolkits were made to meet different needs, a question central to this paper.

The African Middle Pleistocene that began from 781-126 ka is a crucial period for human evolution, as it witnessed both the lithic turnover from the Early Stone Age, to the Acheulean Industry and the origin of the evolution of modern human lineage. Kanapoi is one such site. The site is renowned for producing some of the earliest evidence of Australopithecus in the deposits dated to 4.195 - 4.108 years old.

Despite yielding very rich hominids and fauna remains, little is known about the archaeology of Kanapoi. Hominid behavior in the manufacture of stone tools that allowed them to survive in drastically changing environmental conditions, remains poorly reported from the site. The only existing literature that ties Kanapoi to hominid stone tool culture is an article by Mary Leakey that dates back to 1966. Using the newly published book on the (Prehistoric Stone Tools of East Africa), lithics from Kanapoi sites were analyzed. Preliminary results point towards a decrease in the size of artifacts in the assemblage from choppers to prepared cores and points. In addition, it points towards the decreased amount of cortex from ESA pieces to MSA-prepared cores. This pattern is unexpected because there are no artifacts that can be associated with the remains of the *Australopithecus anamensis.*

These findings indicate that early hominins had the ability for complex thought required for the procurement and use of resources on the landscape, making them adaptable to changing environments. This study expands the breadth of knowledge on hominid behavior and settlement patterns, adaptability, and resilience strategies during the early Pleistocene.

KEY Words: Settlement, hominids, lifeways

A new Early and Middle Stone Age site in West Turkana, Kenya

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The Acheulean/Middle Stone Age (*MSA*) transition in Africa is often described as a pivotal period in human evolution, manifested by an increasing technological innovation and a regionalization process associated with the evolution of *Homo sapiens*. This view of the archaeological record is based on a continental-wide perspective which opposes two large scale patterns – one, a, theoretically, homogeneous and technological persistent production of large bifacial tools (hallmark of the Acheulean), and the other, a diversity of forms and production methods of the small shaped tools characteristics of the *MSA*. However, very few sites have yielded both Acheulean and *MSA* materials, thus allowing for a more accurate understanding of these changes at a regional scale (ex. 8-B-11 site, Sai Island, Sudan or Garba III, Melka Kunture, Ethiopia).

Here we report on the technological assemblage retrieved from a new site discovered in 2017 in the South-West of the Turkana Basin. Kanyimangin is located within the Kalabata river (an affluent of the Kerio river) circular anomaly, where approximately 15 meters deep sediments are preserved from erosion by a series of five sandstones. Combined palaeomagnetism and biochronological approaches have yielded an age estimate between 0.90 and 1.19 million years old for the site.

344 lithic artefacts have been recovered from the site; 72 originate from two archaeological test pits, while the remaining artefacts were found through archaeological surveys.

The material discovered in the excavations and on the surface appears to have similar technological characteristics. Cores with simple debitage methods (unipolar and convergent), discoidal cores and different types of handaxes are consistent with a possible early and middle Pleistocene occupation of the area of Kanyimangin. However, the presence of Levallois cores and flakes with platform preparation indicate a Middle Stone Age component, whose depositional process still need to be defined.

Even though that majority of the technological information available today comes from surface material, the good preservation of some artefacts together with the presence of some technological refits document the potential of the area from an archaeological point of view.

Holocene hydroclimate reconstruction from tropical South Pacific lake sediments – Emaotfer Swamp, Vanuatu.

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The South Pacific was one of the last regions on Earth to be colonised by humans. Human migration in the Pacific occurred in two waves, the first started 3000 yrs BP and saw the Lapita civilisation colonise remote Oceania eastward to Samoa. The second occurred after a long pause approximately 1000 yr BP and saw the colonisation of the three corners of the Polynesian Triangle. Reasons for these migrations are contested, but climate is increasingly thought to have been a factor. Whilst the tropical Pacific experiences high levels of rainfall – up to 6000 mm a year - island communities can experience droughts that put pressure on populations on islands with area limited carrying capacity. Palaeoclimate evidence suggests the South Pacific has experienced shifts between dry and wet periods throughout the Holocene. To date, very little is known about the climate in the tropical South pacific during the first wave of human migration into the pacific, limiting our understanding of its role in decisions to undertake voyaging and subsequent settlement.

Using lake cores from Emaotfer Swamp which is located on the Western pacific island of Efate in Vanuatu, this study utilises a multi-proxy approach including stable isotopes from inorganic and organic material along with Itrax µXRF data to reconstruct a hydroclimate and environmental record over the Holocene. The objective is to identify how the climate has changed over the Holocene in this region and whether there are any synchronicity between changing climate and the timing of human migration and colonisation. The site is adjacent to Teouma, one of the earliest Lapita occupation sites in Vanuatu, constraining the local presence of humans to c. 3000 yr BP. The key findings from the palaeoenvironmental record from Emaotfer are the presence of two potential dry periods occurring 5880-6730 ± 350 yr BP and 531-2131 ± 157 yr BP, the second of which encompasses the period of the second migration phase into Oceania. Thus this study offers new insights and a new record of climatic and environmental change during the Holocene and at the time of human migrations in the western tropical South Pacific.

Newly-developed reliable post-1950AD atmospheric 14C record for the tropics using absolutely dated tree rings from Equatorial Amazon

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To calibrate past and present atmospheric radiocarbon (^{14}C) fluctuations, compilations of atmospheric ^{14}C levels using robust archives are required. The last couple of centuries, and specially from 1950 to present, have seen substantial changes in atmospheric ^{14}C. Changes are mostly attributed to burning of fossil fuels (which contain the carbon isotopes of ^{12}C and ^{13}C, but no measurable ^{14}C) and the artificial injection of bomb-derived ^{14}C during the nuclear era (the middle 1950s to early 1960s). Those man-made contributions to atmospheric ^{14}C and the current response of the Earth's system to them are relevant for better understanding of the carbon-cycle, past records and future climate changes. Several efforts have been made to monitor those changes. Present global post-1950AD atmospheric ^{14}C compilations consists of hemispheric and zonal datasets divided into summer for use in carbon-cycle studies, and monthly for more accurate ^{14}C dating of recent terrestrial samples. However, datasets close to the equatorial line still lack high resolution in both space and time. To develop an extended and continuous atmospheric ^{14}C record from 1940-2016, 77 single tree rings from an absolutely dated *Cedrela odorata* sample from Eastern Equatorial Amazon (1°S, 53°W) were measured by high-precision ^{14}C accelerator mass spectrometry (AMS) in replication. A set of 175 radiocarbon measurements have been produced, including results from precise cuts of single tree rings from the calendar years 1962 and 1963 (confirming the calendar's sub-annual tissue growth), and interlaboratory comparisons. Interlaboratory ^{14}C measurements yielded an outstanding precision of 0.17%. From 1970 onward, the Eastern Equatorial Amazon ^{14}C record confirms enhanced-^{14}C due to land respired CO_2 containing high levels of post-bomb radiocarbon. Because of its position (just above Amazon River downstream and estuary areas), this ^{14}C record has not been affected by the local fossil-CO_2 derived from trade route networks operating in Central Amazon Basin. Thus, our new tree ring ^{14}C record will enable for the extension of atmospheric ^{14}C compilations at lower latitudes to a more recent time period, re-evaluate longitudinal symmetries, and to improve determination of zonal borders.

pSESYNTH Project: early insights into building a multidisciplinary paleo-database of the Global South

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While the theoretical basis for fruitful interdisciplinary studies in paleosciences has already been identified, efforts to find feasible strategies to put it into practice using more inclusive and democratic approaches necessitate continued mobilization and collaboration. The lack of such efforts is seen across the Global South, the regions of Latin America and the Caribbean, Africa, Asia, and Oceania, which have been historically marginalized from scientific collaborations. The study of past socio-environmental systems is underrepresented in these regions – yet their diverse landscapes ranging from tropical forests to high-latitude grasslands under climatic as well as anthropogenic threats urge for unbiased understanding of long-term human-environmental dynamics. Such understanding is key to improving the knowledge of pressing environmental issues in the Global South regions inclusive of the most, if not all, developing countries in the world. This has been the core challenge being tackled by the INQUA-funded project titled "The whole is not the sum of the parts: building a synthesis database of past human-environmental systems in the Global South" (pSESYNTH). During 2022, pSESYNTH has taken its first steps to foster collaborations among paleoscientists across the Global South, with the prime goal to build the first-ever multi-disciplinary database of past socio-environmental systems from the regions. The team of more than 55 paleoscientists from 20 different countries with diverse expertise including paleoecology, paleoclimatology, archeology, and data science, have actuated discussions on how paleo-datasets from the respective regions can be fairly consolidated so that they can act as practical analogs of present and project future trends. Through drawing leadership among the ECR cohort, pSESYNTH has encouraged hands-on opportunities for developing three region-specific subgroups – Americas, Asia-Africa, and Australasia-Oceania – that have been stimulating community-led research questions and synthesis of Holocene datasets at the intersection of climate, humans, and environment. While pSESYNTH will continue through 2025, here we bring a summary of the project's initial efforts for knowledge and data exchange, exploration of ideas that link disciplines and approaches, and R Shiny App-based data visualization, all leading to an open-to-all Global South database in the near future.

Environmental history over the Late Holocene from an extreme peatland ecosystem in Cape Horn archipelago, Isla Hornos (Isla Lököshpi), Southernmost South America (~56°S)

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The geographical location of Cape Horn (~56°S) is unique due to its being the southernmost landmass in the Southern Hemisphere (outside of Antarctica), and it reflects the direct influence of the ocean-atmosphere-land interactions which comprise the southernmost forest on the Earth: an ecotonal ecosystem highly sensitive to climate change and with low anthropogenic impact. In this study, we present a multiproxy analysis of two sediment cores taken from a bog dominated by vascular peat-forming cushion plants at Isla Hornos (56°S; 67°W) to examine past variations in the environment during the Late Holocene. A 150 cm core (IH-F-1) was taken from the periphery of a peatland next to *N. betuloides* forest and analysed for pollen and spores to reconstruct the vegetation changes. Peat accumulation was relatively rapid (~0,1 cm/year, spanning *c*.1.6 ka). The vegetation records supported by loss on ignition and tephrochro reveal insights into the environmental history (LIA, c.0.6-0.5 ka) throughout the last millennia at Isla Hornos. To address weather periods of climate, environmental and ecological conditions correlate with archaeological evidence of human occupation on Isla Hornos (1428-1803 CE, previously dated). A second 60 cm core (IH-F-2) was taken from the middle of the peatland (peat accumulation ~0,02 cm/year, spanning *c*.4.2 ka) was analysed to reconstruct the changes in vegetation, and Micro-X ray fluorescence (μ-XRF) ITRAX scanning was conducted to identify major geochemical changes in the record. Optical and X-ray imaging, and magnetic susceptibility data were also carried out to characterise the sedimentology and stratigraphy and to support the paleoenvironmental analysis. The sediment cores were constrained by AMS ages. The records were compared (via statistical analyses and numeric techniques) with more than 10 palynological peat records across Fuego-Patagonia (~52-55°S) to reconstruct past ecosystems changes and to infer shifts climate drivers across the region. Preliminary results suggest major shifts in the pollen abundance and chemical proxies occurred at *c*.1.6 ka. The records also show centennial-scale climate variation in climate, which in turn has been teleconnected to variability in Antarctic temperatures and the position/intensity of the Southern Annular Mode during the Late Holocene.

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Palaeoecological changes based on palynological records during the Late Holocene; connections with changes in maritime cultural traditions, Southern South America (~52-56°S).

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The climate-environmental change is a key issue for understanding the pathways and/or the adaptive strategies used by past human populations and the complex connections with the physical environment over the time. However, few studies have improved proxy-based environmental reconstruction to achieve more accurate comparisons between past environmental conditions and human behaviour. The objective of this study is to reconstruct the past vegetation changes based on palynological records during the Late Holocene (*c.*4.2 ka) and to integrate and evaluate the connections with changes in the first highly specialised maritime cultural traditions in a key archaeological area in central Estrecho de Magallanes (~53°S). We present a synthesis of six palynological records taken from peatland, which was constructed using continuous well-dated records, two new and four previously published. Tephrochronology (new ages are presented) was used to link records among sites to produce enhanced and reliable past environmental scenery. Then, ^{14}C ages information for periods of temporal and cultural discontinuity was analysed to represent the human occupation as summed probability distributions of calibrated radiocarbon ages. Our synthesis, based on CONNIS cluster analysis, shows that different vegetation ecosystems (sites) responded relatively synchronously (vegetation assemblages) to climatic changes suggesting the same millennial-scale climate variability forcing. Pollen assemblages were delimited at c.4.2-3.3 ka; 3.3-2.2 ka; 2.2-1.6 ka, and the last c.1.6 ka. However, a major climatic and ecological discrepancy was registered at c.3.3-2.2 ka among the records analysed. Discrepancy in term of change in cover forest, pollen preservation, emergence of Pediastrum algae in some peatlands and different patterns of fire activity among the sites, suggesting that our records are marked by increasing ecological instability driven by increasing centennial-scale climate variability. In this study, we discussed, in detail, the ecological instability of this period, likely the ecosystems being driven across tipping point thresholds, and the connection with a maritime culture change during this period. Similar threats, faced by past societies, continue to be one of the main challenges for improving the quality of life today because we live an unprecedented world scenario of environmental and climatic crises.

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The Early Pleistocene fossil assemblage from Incarcal-I (Fluvià Valley, NE Spain): first numerical dating results.

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In this work, we provide the first numerical dating results for the palaeontological locality of Incarcal-I (Fluvià Valley, NE Spain), which is famous for its latest Early Pleistocene large mammal assemblage, especially rich in large carnivorans such as the sabertoothed cat *Homotherium*. The locality belongs to a karst complex formed in the so-called limestone of Crespià, in which a series of sinkholes with associated sedimentary infills has been identified and studied over the last four decades. In particular, systematic excavations carried out in one of these cavities, Incarcal-I, have provided ca. 2,000 remains attributed to at least 15 taxa of large mammals. The chronology of this site was initially inferred from biochronology to between 1.5 to 1.2 Ma, depending on the studies. However, Incarcal-I had never been numerically dated until now.

To fill this gap, two molars of *Hippopotamus antiquus* were selected from the Incarcal-I sample for combined U-series/Electron Spin Resonance (ESR) dating in combination with a sequential magnetostratigraphic sampling. The teeth were processed following the most advanced analytical procedures: various enamel samples were collected from each tooth (n=7-10), while several laser ablation ICP-MS U-series profiles were carried out across dentine, enamel and cement in various domains of the teeth. Interestingly, analytical results show very homogenous spatial distributions of the ESR and U-series data. Environmental dose rate was evaluated through numerous laboratory and *in situ* measurements, also showing relatively little lateral variability. First numerical dating results provide a latest Early Pleistocene age for the faunal assemblage, i.e. consistent with previous biochronological estimates, although somewhat younger. Discussion will be focused on the existing uncertainty associated to these numerical age results and the biochronological implications.

Coelodonta antiquitatis dietary adaptations and geographical patterns: responses to palaeoenvironmental changes during the MIS 3

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Coelodonta is one of the emblematic taxa of the Mammoth steppe or the *Mammuthus-Coelodonta* faunal complex. Its first representative occurred in the Tibetan plateau during the Pliocene and, through time it expands widely through Asia and Europe. In Europe, *Coelodonta* reach its peak of expansion during MIS 3 under the form *Coelodonta antiquitatis* with a territory covering almost all the continent including the Southern peninsulas. With its hypsodont teeth and its low head carriage, *C. antiquitatis* is often seen as a grazer specialist well-adapted to the European steppes. Its range of expansion, however, indicates that it inhabited various type of biota. While MIS 3 is considered as a cold stage, the environmental conditions varied greatly from an open steppe in the North of Europe to the persistence of Mediterranean forest in the South. This raises the question of the flexibility of *Coelodonta* and its aptitude to inhabit new biota. In this presentation, we aim to discuss the dietary adaptations of *Coelodonta antiquitatis* using dental wear analysis. Thirteen sites dated of the MIS 3 and located in the North Sea, Britain, Germany, France and the Iberian Peninsula were selected. Our results suggest that *Coelodonta antiquitatis* was, in fact, a flexible species that was very prosperous in the Northern steppe but also able to change its behaviour in the South. Its diet appears more abrasive in South of Europe than northern Europe according to microwear and the opposite according to mesowear. This work will discuss the differences between the two proxies. *Coelodonta* capacity to adopt various diet may explain both its success and its wide range of expansion. It may also explain the conservation of several population in South western Europe during warmer climatic period.

The Hippopotamus skull from the Tor di Quinto area (Rome, central Italy) and its troubled history

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The earliest dispersal of *Hippopotamus amphibius* in Europe has been widely discussed in paleontological literature. Two different hypotheses have been proposed: i) a diffusion occurred during the early Late Pleistocene, based on the record of Barrington locality (MIS 5; United Kingdom); ii) a Middle Pleistocene dispersal, at approximately 0.5 Ma (MIS 13), according to the finding from the Tor di Quinto area (Rome, Italy).

The skull from the Tor di Quinto area, stored at University Museum of Earth Science (MUST), Department of Earth Sciences, Sapienza University of Rome, has been studied by several authors, and always attributed to *Hippopotamus amphibius*. The debate, instead, was and is still focused on its geographical provenance and age. The original toponym, as reported in the first work, was Cava Montanari, but later considered as Cava Nera Molinario. Recent restoration works on the hippopotamus skull from Tor di Quinto area, revealed the presence of clastic sediments inside the cavities of cranium and mandible, and around the teeth. The petrographic analysis of the sediment sand fraction offers the possibility to obtain direct information about the provenance of the deposits and thus to infer the age and stratigraphic context of the enclosing sedimentary unit.

Herein, we present new morphological and biometric analyses of the skull from Tor di Quinto area, after the restoration works. In addition, we investigate the geographical provenance and age of the specimen through the study of archive documentation and historical geological maps, by combing these data with new sedimentological analyses. The results allow to clarify the earliest dispersal of *Hippopotamus amphibius* in Europe, an important bioevent for terrestrial palaeocommunities.

Carrying capacity, available meat and the fossil record of the Orce sites (Grenada, Spain)

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The Early Pleistocene sites of Orce (Guadix-Baza Depression, SE Spain) record the first hominin populations in Western Europe and provide a wealth of information on the Late Villafranchian large mammal communities. Dated to around 1.4 Ma, Fuente Nueva-3 (FN3) and Barranco León (BL) preserve abundant Oldowan tools, cut and percussion marks on fossils, and a human deciduous tooth in BL. Research during the last three decades has led to the conclusion that the hominins and giant hyenas (*Pachycrocuta brevirostris*) played an essential role in the FN3 and BL accumulations, accessing secondarily the meat resources exploited by saber-toothed felids. Venta Micena (VM) (≈1.6 Ma) is another outstanding Orce site, which preserves an exceptionally rich large mammal assemblage. The VM record predates hominin presence in this region, which provides a point of interest for understanding the previous conditions to the first humans in Western Europe.

Our aim is to analyze whether the record from these sites can be correlated with the representation that the herbivorous mammals had in the paleocommunity and/or with the meat that carnivores and humans could obtain from them, and to compare VM with FN3-BL assemblages. We estimate the carrying capacity (CC) and meat availability (TAB) of the large herbivore community of VM, FN3 and BL, and compare them with the relative abundances of the species at these sites. Estimates are made using paleoecological models that consider survival and mortality profiles.

Results show similar relative percentages for CC and TAB values, although differences are observed between VM and FN3-BL: TAB is more balanced across different body mass categories in FN3-BL than in VM. Comparison with the frequencies observed in the assemblages from the sites shows that both the Upper Level of FN3 and level D of BL resemble the estimated values for CC and TAB. However, the Lower Level of FN3 has a high representation of *Equus altidens*, a pattern not like any of those estimated for CC or TAB. In the VM quarries there is a higher relative abundance than expected of species with medium-to-large body masses and lower of species with extreme, small and very large masses.

Zooming in on the micromammals using microtomography

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The recent increase in the use of virtual palaeontology has marked the exploration of a new frontier, especially in three-dimensional imaging of fossil specimens using computed micro-tomography. Some studies have already demonstrated the potential of extracting data from the interior structures of fossils in 3D, digitally correct for deformation and/or fragmentation of the fossils, and even test the biomechanics. In the case of micro-vertebrate fossils, these new techniques allow tiny specimens to be studied without any physical stress or damage, which is of especial interest for rare or type fossil specimens.
Soricids (i.e., shrews), due to their tiny size, rarely preserve complete diagnostic elements in the fossil record. Because their taxonomy is exclusively based in dentognathic remains, postcranial elements of soricids have been largely ignored by most of the specialized authors. In the present study, we have selected some soricid fossils (including several humeri clearly ascribed to one species) and they have been scanned using a micro-CT to study some of their morphological peculiarities. Shrews (and insectivores in general) have shown to be very useful in palaeoecological analyses. With the 3D models resulting from the micro-CT scans, new qualitative and quantitative data is being recovered from this exceptional fossil material. The peculiarities of these humeri of shrews not only potentially tell us about the preferred way of moving (running, diving, burrowing), but they could also provide interesting information about the ontogeny of the individuals. This could be potentially very useful in reflecting local environmental changes, allowing us to further enhance the resolution of palaeoenvironmental reconstructions. Additionally, as suggested by some researchers, combining this data with other techniques such as histology and molecular phylogenetics can be the key to resolving the mess of taxonomic classification of insectivores. However, the biggest limitation is the resolution of the data, it still is not easy to observe potentially useful micro-structures.

Middle Pleistocene hippopotamuses from the Guadalquivir River (southern Iberia)

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Middle Pleistocene vertebrate assemblages from fluvial deposits of the Guadalquivir River at La Rinconada (Seville) (ca. 0.4-0.38 Ma) have yielded specimens of *Hippopotamus* sp., together with *Equus ferus*, *Palaeoloxodon antiquus*, Bovidae and Acheulean industries. In this chronological range, it has been hypothesized a turnover in Europe of hippopotamus populations, with the entry of *Hippopotamus amphibius* and the subsequent disappearance of *Hippopotamus antiquus*. In the Iberian Peninsula, *H. antiquus* is estimated to have been present since ca. 1.7 Ma, being especially abundant in the Early Pleistocene lacustrine palaeoenvironments of the Guadix-Baza Basin and in the Early-Middle Pleistocene localities of the north-eastern Iberian Peninsula. Scarce are the findings in fluvial terrace, such as the Júcar and Guadiana rivers; or the deposits in caves, as in Sierra de Atapuerca sites or Pontón de la Oliva. *H. amphibius*, on the other hand, has a less clear record and is represented by dubious attributions. Specimens dated from the Mid-Middle Pleistocene (terraces of the Tajo and Jarama rivers, Mealhada or Cova de Bolomor, among others) to the Upper Pleistocene (Cova del Toll and tentatively Cueva de la Lloseta) are attributed to this taxon. In most cases, the presence of *H. amphibius* is associated with lithic industry, as well as with the faunal associations observed in La Rinconada. The presence of these taxa is usually interpreted as an indicator of temperate climatic conditions with permanent presence of water bodies and grasslands. It is more controversial to use the presence of hippopotamuses as a biostratigraphic indicator, as there is no consensus on the taxonomic assignment at the specific level of isolated teeth or most postcranial elements. In La Rinconada Middle Pleistocene sequence, the presence of large canines together with smaller specimens stands out, which has facilitated the consideration of a biometric range in these populations. The results of this study contribute to the context of the transition between the presence of *H. antiquus* and *H. amphibius* populations in Europe, as well as providing valuable information for the environmental reconstruction of the environment of human populations in the south of the peninsula during the MIS 11 climatic optimum.

Pleistocene woolly rhinoceros skulls: A methodological approach

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Fossil rhinoceros remains are fairly well represented in the Quaternary fossil record. This is especially true for the woolly rhinoceros (*Coelodonta antiquitatis*). Studies of these finds have taken morphological, osteometric, taphonomic, genetic, and other approaches. The osteometric studies in particular show noticeable nonuniformity in the cranial measurements they present. If we are to consider morphotypic variation within species, skulls with cognitive potential on the taxonomic level should be measured using the same approach.
Our presentation will focus on a methodological approach to the measurement of woolly rhinoceros skulls from Late Pleistocene contexts by proposing a new protocol for skull measurement. Ontogenic, morphological, and osteometric perspectives on rhino skulls will be discussed.
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The Anagni Basin: an Early to Middle Pleistocene palaeontological and archaeological key area in the mammals biochronology of the Euro – Mediterranean Quaternary

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The intramontane basin of Anagni (central Italy) hosts three of the most important palaeontological and archaeological sites in Italy, Coste San Giacomo, Colle Marino and Fontana Ranuccio, spanning from 2,2 to 0,4 Ma (Early to Middle Pleistocene). In the last decades an intense scientific activity has been carried out, promoted and coordinated by the Italian Institute of Human Palaeontology (hereinafter IsIPU) in collaboration with different national and international Institutions. Dedicated bore cores, field surveys excavation campaigns and extensive reviews of the archeological and paleontological material housed at IsIPU have resulted in a number of scientific publications that contributed to analyze the dynamics of the mammal fauna of the Mediterranean Europe during the Pleistocene, also providing new constraints to better interpret the location and spatial distribution of early *Homo* during the Middle Pleistocene occupation of this area.

In this work we present a comprehensive state of art of the palaeontological and archaeological research achieved in the last years on the Anagni basin and new data coming from taxonomic analyses performed on the large mammal remains of the aforementioned sites.

Palaeoclimatic and palaeoenvironmental reconstruction for the Late Pleistocene Melitzia Cave, Mani Peninsula Greece from oxygen and carbon isotopes of ungulate enamel

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The Balkan Peninsula is one of the regions that have acted as refugia during the Last Glacial Period, and due to the favorable climatic conditions, it hosted faunal communities, including humans. Mani Peninsula, in the southernmost part of continental Greece, is a key area for Palaeolithic studies due to the large number of excavated sites containing deposits with cultural artifacts and skeletal remains from the Middle and Upper Palaeolithic, revealing the abundance of human occupation in the wider area during the Middle-Late Pleistocene. Melitzia Cave is one of several karstic cavities discovered on the western coast of the Mani Peninsula that were used by Late Pleistocene hominids as a shelter. The excavated Upper Palaeolithic cultural layers at Melitzia Cave are well dated covering the timespan between 45,500±947.5 BP and 10,915±235 BP. Fallow deer, red deer, and caprine dominate the faunal assemblage.

Here we reconstruct palaeoenvironmental and palaeoclimatic conditions around the cave across the period of the Last Glacial maximum using a stable isotope approach on teeth of the three most abundant ruminant taxa. Their third and second molars were analyzed for stable carbon and oxygen isotopes ($\delta^{13}C$ and $\delta^{18}O$) using two different sampling strategies: bulk enamel reflects the average diet and the hydrological conditions experienced by the animals during the enamel mineralization period, whereas sequential samples along the tooth growth axis track seasonal dietary and environmental changes. Bulk enamel samples of all three ruminant taxa have a mean $\delta^{13}C$ value of -10.2±1.1‰ (n =26; range: -6.5‰ to -12.2‰), reflecting a predominant consumption of C_3 plants such as trees, shrubs, herbs and/or C_3 grass. No major changes in vegetation cover seem to have occurred as the $\delta^{13}C$ values do not display clear changes with time nor between taxa. The mean $\delta^{18}O$ value is -3.3±1.1‰ (n =24; range -5.4‰ to -0.9‰) with a high variance of 2−3‰ in different time bins but no clear changes with time are observed. Serial sampling will provide a more refined picture of seasonality and changes thorough time. Implications for environmental and climatic conditions in this southeastern European refugium during the Last Glacial Period will be discussed.

Overview of the Caprini record from the Early Pleistocene of South Europe, with description of new material from Aghia Kyriaki (Aetoloakarnania, Greece).

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The Early Pleistocene Caprini record of South Europe includes the genera: *Hemitragus* (Late Pliocene—Middle Pleistocene), *Pliotragus* (Late Pliocene—Early Pleistocene), *Euthyceros*, *Procamptoceras*, *Gallogoral*, *Megalovis* (Early Pleistocene), *Soergelia* (Early—Middle Pleistocene), *Praeovibos* (Pleistocene) and *Ovis* (Pleistocene—present).

During this period, *Soergelia* and *Praeovibos* were widespread in Europe, whereas *Gallogoral*, *Procamptoceras*, *Megalovis*, *Pliotragus* and *Hemitragus* were relegated in Southern Europe. *Ovis* is evidenced only in Greece, Bulgaria and France, but, later on, the taxon dispersed all over Europe. *Euthyceros* is endemic of Greece, known only from the locality of Sesklo. *Hemitragus* is represented by two species during the Early Pleistocene: *H. orientalis* (Hungary, Bulgaria, Greece, France) and *H. albus*, possibly endemic to the Iberian Peninsula.

A recent preliminary palaeontological study of the site Aghia Kyriaki (Aetoloakarnania, Greece), allowed the identification of 13 different mammalian taxa, suggesting an estimated age of 2.5—1.8 Ma, corresponding to the Middle to early Late Villafranchian. Among the studied material, we attributed few remains to cf. *Procamptoceras brivatense* and *Hemitragus* sp.

The fossil record of both these genera in Greece is scarce. *Procamptoceras* is recorded in Vassiloudi 1 (Mygdonia Basin) and possibly in Volax (Drama Basin), whereas *Hemitragus* sp. is recorded in Mygdonia Basin in Apollonia I (1.2—1.0 Ma) and Krimni-3 (1.8—1.5 Ma) by scanty remains. The new findings from Aghia Kyriaki represent the southernmost presence of the two genera in Greece so far, as well as the earliest presence of *Hemitragus* in Greece.

Most Caprini are quite common in SE and SW Europe, whereas they seem to be poorly represented in other European areas (i.e., North—Central Europe and Italian peninsula). The reasons for this restricted geographical distribution are still not widely addressed. Although the scarcity of Early Pleistocene localities in North—Central Europe could lead to a bias in the fossil record, environmental factors (i.e., ecological preferences) might have played a major role in this matter. Moreover, the Asian origin of many Caprini could explain their stronger presence in Eastern and Southeastern Europe during this period. Further studies are required in order to clarify the dispersal dynamics that characterize this group of bovids.

Quaternary large mammals bioevents in the Italian Peninsula

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The Quaternary is a time of fundamental climatic shifts and environmental changes that caused a diverse response of the biota. An updated chronology of major bioevents formalized in Italy is summarized and discussed in relation to changes observed in other geographic regions as revealed by the new data.

The beginning of the Quaternary coincides with the extinction of several taxa of subtropical affinities and the spread of a primitive mammoth (*Mammuthus rumanus*) and a monodactyl equid (*Equus* cf. *livenzovensis*). Nonetheless, the paucity of sites of this age likely sharpens the turnover and, in any case, the dispersal of the mammoth is not synchronous across Europe. The “wolf event” is older than what hypothesized 40 years ago, with *Canis* sp. being first documented at Coste San Giacomo at ~2.2 Ma. The same site also recorded *Hippopotamus* sp., which is the earliest well-dated Middle Villafranchian occurrence of a hippo in Europe.

At ~2.0-1.8, the Late Villafranchian witnessed the arrival of the giant hyena *Pachycrocuta brevirostris* and *Panthera gombaszoegensis*. Early faunas of this period document a peak in carnivoran diversity, with the giant hyena being an especially important component for ~1 Myr.

The replacement between *P. brevirostris* and *C. crocuta* occurs at ~0.8 Ma, between Slivia and Ponte Galeria Faunal Units, at the Epivillafranchian-Galerian transition. This also roughly coincides with the replacement between *Sus* cf.*strozzii* and *Sus scrofa*, although suid remains are seldom abundant. Galerian faunas of the early Middle Pleistocene are characterized by the extinction of old Villafranchian species and the dispersal of several newcomers. The general pattern is quite clear, but the timing of these bioevents is not always well-resolved or synchronous across Europe.

In 1997, Italian researchers proposed the Aurelian Mammal Age to name the renewal coinciding with the establishment of “the core of the modern mammal fauna” started in the late Middle Pleistocene. The most important bioevents chosen to typify the Aurelian, namely the appearances of *Canis lupus* and *Ursus spelaeus*, are now recognized as older than previously believed and major faunal and environmental changes seem closer to ~0.4 Ma.

Saccopastore (Rome, Italy), a reappraisal: Neanderthals, large mammal fauna, history and geo-stratigraphy of the site

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Saccopastore is a well-known historical site in the north-east countryside of the city of Rome (Italy), located within a meander of the current stream of the Aniene river (tributary of the Tiber), now largely within and buried below the urban development. The stratigraphical succession of Saccopastore was exposed by open-air quarry activities during the early 20th century. In 1929, a human cranium was stumbled upon by workmen; Sergio Sergi ascribed it to *Homo neanderthalensis*. The quarry was then abandoned, but six years later a second Neanderthal cranium was discovered by Alberto Carlo Blanc and Henri Breuil during a geo-paleontological survey. The discoveries prompted the Italian Institute of Human Paleontology (directed by A.C. Blanc) to start systematic excavations in 1936. During fieldwork, well-stratigraphically constrained mammal fossils and Mousterian lithic tools were recovered, which have been added to those already found previously in different layers of the stratigraphy. The stratigraphical succession of Saccopastore was studied by various authors and framed within the widest geological context. The horizon where the two Neanderthals were found was unanimously attributed to the early Late Pleistocene (Marine Isotopic Stage 5e; Eemian). During the last decade, however, a chronostratigraphic reassessment of the deposits throughout the area of Rome (lower basins of the Aniene and Tiber rivers) has claimed for an older age (Marine Isotopic Stage 7). We therefore started a project of reappraisal of the Saccopastore "cold case", focused on the revision of geological and stratigraphical setting of this important site and its paleontological content. The study of archive documentation (photos, geological sections, excavation journals) and geological maps, combined with new sedimentological and geochemical analyses on the original sediments (collected during the '30s excavations and still preserved in the Sergi's Museum), will allow to better define the chronological framework of the Saccopastore succession. Concurrently, the revision of the mammal fossil assemblage will also provide new data on the faunal composition and the environmental setting at the time when these early Neanderthals lived.

An approach to the predator-prey power law in past ecosystems and the reconstruction of early human populations in Western Europe

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In a study of modern ecosystems, Hatton et al. (2015) observed that predator biomass scales to a power close to ¾ of prey biomass. This type of relationship is also held between body mass and other biological parameters (eg., metabolism, production, or consumption).

During the Early Pleistocene in Europe, the relationship of the first hominids with carnivores and the prey community may have conditioned the stable presence of hominid populations since meat was a key resource in their dispersal. The modeling of trophic relationships in the communities of Pleistocene large mammal can thus provide information on the ecological conditions in which these early humans developed their lives.

The rich fossil record of the archaeological sites of Orce (Granada, SE Spain) and Sierra de Atapuerca (Burgos, N Spain) offers an exceptional opportunity to analyze the paleocommunities of early humans in the Iberian Peninsula. At Orce, the Barranco León and Fuente Nueva-3 sites show the oldest evidence of human presence in Western Europe, dating to ~1.4Ma. In addition, the nearby Venta Micena site preserves an excellent record of the paleocommunity prior to human presence in the area, thus opening interesting clues on the human exploitation of niches. In the case of the Sierra de Atapuerca sites, they have provided an important collection of human fossils that make these sites unique worldwide. Moreover, these sites preserve a nearly continuous record of the faunal assemblages that inhabited this region in NW Spain more than a million years ago.

Our aims in this work are to reconstruct the biomass ratio of predators (predators, scavengers, and hominins) to their prey in the Orce and Atapuerca sites, and to analyze if these ratios are like those obtained by Hatton et al. (2015) for the African communities. For doing so, we estimate the biomass of predators and prey based on previous studies of the trophic networks of these paleocommunities.

Our results show that the modeling of the Orce and Sierra de Atapuerca paleoecosystems complies with a relationship like that obtained by Hatton et al. (2015) for the African ecosystems (i.e., a scaling with a power close to ¾).

Comparative analysis of brain endocasts in living and extinct "Big Cats", and their implications in paleoecology

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Felidae is a family of the order Carnivora, characterized by the extant subfamilies of Pantherinae and Felinae, and the extinct Machairodontinae and Proailurinae. The Pantherinae subfamily is represented only by the genus *Panthera*, and includes the "big cats" of the family (lions, leopards, tigers and jaguars). On the other hand, the Felinae includes felids of different genera (*Acinonyx*, *Puma*, *Lynx* and *Felis*). Despite the difference in subfamilies and genera, the brains of living felids are strikingly similar to each other in their external morphology, with little differences reflecting their ecological adaptations. Conversely, the fossil felids show very different morphologies between genera, probably reflecting derived traits and stronger ecological adaptations.
Here we present a discussion on the main morphological traits in brains of both pantherines (extant and fossil specimens from the Middle Pleistocene to recent) and machairodontines as the Late Pleistocene sabertoothed species *Smilodon fatalis*, in order to investigate different encephalic response to different adaptations in living and extinct "big cats" subfamilies, sharing similar ecological niches.

The Quibas site (Murcia, Spain): New herbivores from the early-middle Pleistocene Transition

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The Early Pleistocene site of Quibas, located in Sierra de Quibas (Murcia, Spain) was discovered in 1994 and has since then provided abundant material of typical Epivillafranchian taxa. This biochron belongs to the Early-Middle Pleistocene Transition (1.2 – 0.78 Ma), characterised by a change in orbital cyclicity from a 41 kyr cycle to 100 kyr that intensified the climate and culminated in the most important faunal turnover of the Pleistocene regarding large mammals. The Group of Palaeoanthropology of the National Museum of Natural Sciences (CSIC, Spain) and the Institut Català de Paleoecologia Humana i Evolució Social (IPHES-CERCA, Spain) carried out four field seasons from 2015 to 2018 in the site. These provided fossil material from both structures of Quibas: Quibas-Sima (QS) and Quibas-Cueva (QC). Here we present the assemblage of large herbivorous mammals recovered from the field, including the first citation of two taxa new to the locality: a rhino (Stephanorhinus cf. etruscus) and a bison (Bison cf. voigtstedtensis). We also provide the first description of previously mentioned taxa: the fallow deer Dama cf. vallonnetensis and Sus sp. Together with the remaining herbivores, we revised the geographic affinities of the faunal assemblage, which showed a strong European origin with some regionalism. The large herbivorous mammals fall in the typical Jaramillo taxa, coinciding with previous chronostratigraphic approaches, and compared with other Iberian localities Quibas stands out for the lack of hominin fossils or any evidence supporting their presence in the area. This is a peculiar scenario given the human presence recorded in many of the Early-Middle Pleistocene fossil sites that are contemporary with Quibas.

Early Islamic to early Modern Groundwater Harvesting in Aeolian Sand – A review of Plot-and-Berm Agroecosystems from Western Asia to Iberia

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"Plot-and-Berm" (P&B) agroecosystems are relatively unrecognized but traditional, sophisticated in-situ agricultural utilizations of a shallow water table within loose, coastal and inland aeolian sand bodies, that comprise agricultural hinterlands in arid to Mediterranean climates. The agroecosystem is comprised of a checkerboard array of agricultural plots sunken between 3-10 m high man-made berms coated with sediment, artifacts, or vegetation to limit slope and aeolian erosion. Marine and terrestrial organic materials, archaeological material and sediment, depending on the time and environment of the agroecosystem, enrichen the plot sand into a productive anthrosol.

P&B agroecosystems are sporadically spread between Iran, Turkmenistan, Israel, Gaza Strip, northern Sinai Peninsula, Algeria, southwest Spain and northwestern Portugal. Most of these traditional agroecosystems are active and are undergoing human-inflicted environmental and economical stress. Others are abandoned, deteriorating, changing, or under initial restoration and are potential geoheritage sites.

The Caesarea and Yavneh P&B agroecosystems in coastal sand bodies of Israel, dated by numerical methods along with pottery to the Early Islamic period to early Crusader times (9th-early 12th centuries a.d.) may be the first widespread and successful attempts to cultivate aeolian sand in human history. Based on calculations of the amount of work days required for the earthworks to establish the agroecosystem features, we hypothesize that a regional governance initiated the development of these agroecosystems, possibly in response to religio-administrative calls for a type of *mawāt* (Arabic: "dead") land reclamation. In some places, P&Bs may have locally developed in a bottom-up nature. Though active agroecosystems in Portugal, Gaza Strip and Algeria revenue a wide range of seasonal vegetables and also fruit, initiation of agroecosystem construction was probably combined with an economic incentive and demand for a possibly unique crop.

This study presents categorized data of all of the known P&B agroecosystems by geospatial survey and analysis of using Google-Earth imagery, literature review, geoarchaeological work and absolute and relative dating in Israel, and preliminary surveys in Portugal. It attempts to gain insight on the enigma if this unique agrotechnological knowledge may have been gradually transferred since Islamic times, possibly from the Land of Israel to Iberia and to western Asia.

Holocene deforestation history of NE Belgium: an evaluation of pollen- and population-based approaches for reconstructing land cover

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Several methods to reconstruct past land cover are available which can be roughly divided into approaches based on pollen data and approaches based on (estimates of) historical human population. The two most widely used population-based scenarios – KK10 and HYDE – do not agree on the timing and scale of Holocene anthropogenic land cover change (ALCC). By performing pollen-based reconstructions of past land cover and comparing them with the ALCC scenarios, the accuracy of these models could be further improved. In this study, the REVEALS model and non-metric multidimensional scaling (NMDS) are applied to pollen sequences obtained from multiple alluvial floodplains located in the sandy and loamy regions of northeastern Belgium, thereby obtaining the first regional (semi-)quantitative estimates of Holocene landscape openness for this area. These estimates are subsequently compared to the KK10 and HYDE scenarios.

The two pollen-based reconstructions are overall well in agreement and show that forests in northeastern Belgium reached their maximal cover towards 8500 cal. BP. From the Neolithic period onwards, deforestation is detected in both regions, although the loamy region underwent a more rapid and severe land cover transformation. The agreement between both methods implies that NMDS can still be used for detecting land cover changes in case not all of the necessary parameters are available to run the REVEALS model, although in a semi-quantitative rather than in quantitative way. Moreover, NMDS can provide a better understanding of which taxa are related to a particular type of landscape. Taking into account such insights in the interpretation of the REVEALS model output might help to accurately identify the onset of significant human impact on the landscape. The pollen-based reconstructions indicate quite some variability between the catchments, even the ones located within the same region, which is not reflected by the ALCC scenarios. Since alluvial sites often experienced early anthropogenic impact, including pollen data obtained from such sites could not only improve the spatial coverage and accuracy of current pollen-based land cover reconstructions but also improve our understanding of human transformation of the landscape, which can in turn contribute to an improvement of the ALCC scenarios.

Late Holocene natural and human-induced environmental change reconstructed from peat record using a multi-proxy in an oceanic island (Azores)

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Peatlands can provide robust, continuous, and high-resolution archives of environmental changes. The main factors influencing the evolution of a peatland can be divided into autogenic and allogenic. Apart from climate, human disturbance, such as deforestation and water drainage, are crucial allogenic drivers of change in peatland ecosystems. Here we present the preliminary results of a multiproxy study, including the analysis of plant macrofossils, chironomids, and testate amoebae on a peatland core (4.5 m) from Lake Prata (São Miguel, Azores). The results of the study indicate that the lake ecosystem underwent a classic succession from a lake (700 – 1800 AD) territorialized through to a peatland (1800 AD–until present) and responded to climate and human changes. During the lake phase, two distant periods were identified. From 700 to 1300 AD, human activities were not detected, and plant macrofossils indicate that the catchment area was densely forested. Environmental conditions within the lake were also relatively stable, with lake organic matter dominated by allochthonous sources and chironomid and tecamebas communities of mostly oligo/mesotrophic taxa, indicating stable and relatively low aquatic productivity. From 1300 to 1800 AD, large-scale landscape modifications and the introduction of mammals were recorded, represented by the decline in trees macrofossils, the increase of grasses macrofossils, and the presence of coprophilous fungi at that time. The rise in the dominance of mesotrophic chironomids and tecamebas, indicates a rise in the lake trophic state. Also, a decrease in sediment total organic carbon/total nitrogen (TOC/TN) ratios at this time indicates a transition toward more lacustrine-dominated organic matter in association with higher nutrient levels. From 1800 AD to the present day, drastic changes from all proxies were recorded. Changes in chironomid and tecamebas assemblages from more open-water to macrophytes taxa associated, increase of macrophytes macrofossils, and increase TOC/TN, at this time indicates near-complete infilling and development of a peatland with paludification, and more recently, transformed to a *Sphagnum* peatland. The non-natural conditions of the present-day Sphagnum-dominated habitat illustrate a prime example of why the Habitats
Directive of the EU requires a long-term perspective.

Reconstructing Land Cover and land use changes in the Iron Age of central Italy

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We examine how human and environment relationships have developed over the course of the Iron Age from a regional perspective, and how this relationship manifested in the transformation of land cover and land use. Focusing on the environmental transformation of Central Italy, this paper presents the preliminary results of our investigation into the interaction between the local population and the environment of the region over the course of the 1st millennium BC. This is part of a broader project exploring the connection between environmental modification and identity. It is aimed at estimating how the process of shaping nature into an anthropogenic landscape creates a sense of shared identity among local communities. In our case, tracing the creation of a local Roman identity in some of the earliest activities to modify the environment into a newly what would become the future city of Rome.

Results from the re-analysis of nine pollen sequences will be presented, from eight lakes within 100 km from the city of Rome, including Lago di Mezzano, Lago di Vico, Lago Matiganano, etc. Using age Modelling and the Landscape Reconstruction Algorithm (LRA), the paper sheds light on land use practices within the region and presents information on how specific tree species responded to interactions and helped to shape the anthropogenic landscape. The issues associated with age modeling and re-use of existing data to study land cover changes and linking these with the archaeological record will also be highlighted, including the challenges and limitations of evaluating landscape transformation and reconstructing chronologies based on the characteristics of lake sediments and basin systems. Finally, we briefly discuss the significance of this work with respect to the development of Roman local identities, as the landscape was transformed.

Landscapes of Production: Exploring the palaeoenvironmental context of stone tool quarrying, manufacture, use and deposition on Neolithic Shetland

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The landscape of the Shetland Islands, off the north coast of Scotland, today is a patchwork of farmland, heath and blanket bog. Palynological studies suggest that during the Neolithic the vegetation was much more diverse. Several sites in Shetland show values high of tree and shrub pollen, but due to the problem of wind transport researchers are circumspect about whether these really represent local woodlands, especially in the absence of plant macrofossils to corroborate pollen data.

New radiocarbon dates and reanalysis of Shetland archaeological sites long suspected to be Neolithic, such as Ness of Gruting and the stone buildings at Scord of Brouster, suggest an early Bronze Age chronology for these sites, challenging previously held beliefs about settlement and landuse during the Neolithic and creating a gap in our understanding of this important period. More recently, radiocarbon dates from felsite stone tool quarries in the uplands of North Roe, north-west Mainland, and a cache of polished axes and knives at Modesty in west Mainland indicate extensive quarrying and distribution networks in the early to middle Neolithic. Although found throughout Shetland, felsite artefacts are concentrated on the Northmavine peninsula and adjacent areas of Mainland, reflecting both the natural presence of the raw material and the choices made by the Neolithic inhabitants regarding felsite working practices and networks of artefact distribution.

North-west Mainland has a wealth of Neolithic archaeology and limited palaeoecological coverage, something this project seeks to redress. The upland landscapes around the quarries are different to any sites previously studied in Shetland. Through analysis of pollen and non-pollen palynomorphs from new peat cores, targeting sites close to the felsite quarries and the hoard at Modesty, we examine the landscape context of this important industry and explore Neolithic land-use and vegetation change. This new data is integrated with existing palaeoecological studies to explore regional variations in vegetation. We use pollen modelling approaches to explore taphonomic issues with pollen transport and deposition, and GIS to visualise data, examine variations in land-cover through time, and explore spatial relationships.

Effects of hydrological changes on prehistoric humans in the drylands of the Asian interior

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The causes of prehistoric human movements in the drylands of the Asian interior have long been debated among multidisciplinary scholars. Here, we present the results of the Bronze Age Xiaohe settlements in the extremely arid Tarim Basin of northwest China, whose demise included a long-distance migration along river catchments during ca. 4,000 – 3,300 cal yr BP. We used stable carbon isotope values ($\delta^{13}C$) of archaeobotanical remains, sedimentary face data from the Tarim River catchment, and a compilation of palaeo-environmental evidence in order to investigate the relationships between regional environmental changes and the response of prehistoric societies in this arid region. The results show that the early Xiaohe population was forced to migrate as a consequence of the deterioration of hydrological conditions around settlements. The decline of the Xiaohe Culture occurred in the context of decreasing water availability in the basin interior due to climate change lasting several hundred years. The results are potentially significant for the management of ecologically fragile dryland habitats, particularly the watershed terminus area, threatened by ongoing climate change, specifically in the context of the need to manage scarce water resources to promote sustainable socioeconomic development.

Subsistence strategies of prehistoric hunter-gatherers on the northeastern Tibetan Plateau: zooarchaeological studies of the 151 site

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Successful human adaptation to the high and harsh Tibetan Plateau (TP) marks an important progress in human evolution. Despite the recent rapid renewals of the age of the earliest appearance of hunter-gatherers on the TP, from the Last Deglaciation (~15 ka BP, e.g., Jiangxigou 01 site, the Lower Cultural Layer of the 151 site) to the Late Pleistocene (~40-30 ka BP, Nwya Devu site), and to the Middle Pleistocene (~190 ka BP, Baishiya Karst Cave), we know barely nothing about how these hunter-gatherers survived on plateau before the arrival of millet agropastoral economy in the Late Holocene.

Here we present a detailed zooarchaeological analysis of the faunal remains from the Upper and Lower Cultural Layer (hereafter UCL and LCL, respectively) of the 151 site in the southern Qinghai Lake Basin (>3200 masl) on the northeastern Tibetan. The site was excavated in 2014. The dating results and archaeological remains of the site show that it was occupied by Late Upper Paleolithic and Epipaleolithic hunter-gatherers during 15400-13100 cal yr BP for LCL and 9000-6400 cal yr BP for UCL, respectively. Zooarchaeological analysis of the bone assemblages of the 151 site show that the prehistoric hunter-gatherers in the Qinghai Lake Basin shifted their main hunting strategy from random-hunting of large-sized herbivores (*Bos* and *Equus*) in LCL to specialized-hunting of Przewalski's gazelles (*Procapra Przewalskii*) in UCL. However, “Broad Spectrum Revolution”, indicating the abrupt shift of faunal assemblages to be dominated by small animals, didn't happen in the 151 site. The LCL was composed of a single hearth, indicating that the camp was occupied shortly by a relatively small group of hunter-gatherers, probably only of family size. The rich archaeological remains and thicker cultural deposits in UCL indicate that the site became a regional base camp for relatively long occupations by larger groups of hunter-gatherers in Early and Middle Holocene. From these analyses, our understanding of the spread of prehistoric hunter-gatherers to the TP and human adaptation strategies to the high-altitude environments is greatly enhanced.

New evidence of the earliest microlithic hunter-gatherer occupation on the Tibetan Plateau during the last deglaciation

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Archaeological studies show that microlithic hunter-gatherers started to forage on the Tibetan Plateau (TP) more and more frequently since the Last Deglaciation. Comparing to the current general picture of the spatio-temporal distribution of microlithic sites and the microlithic technology traits on the plateau, we know very little about how these microlithic hunter-gatherers first spread to the Tibetan Plateau. Here, we report a new microlithic site Jiangjunfu 02 (JJF02), with an elevation of 2740 meters above sea level, on the margin of the northeastern TP. ^{14}C and OSL dating analysis suggests that hunter-gatherers arrived at the JJF02 site ~16 ka BP and continued to occupy the site until ~13.3 ka BP. Magnetic susceptibility and grain size analyses show that the weakened East Asian Winter Monsoon during 16-12.7 ka BP provides a suitable natural environment for human survival in the region where JJF02 located. Though only a small number of stone artifacts had been collected during the excavation, it is certain that the assemblage is dominated by microblade technology. The synthesis analysis of the site suggests that JJF02 is a temporary site occupied by high-mobility hunter-gatherers, closely related to the contemporaneous microlithic sites in Qinghai Lake basin. Further comparison studies of microlithic sites in the North China reveal that the spread of microlithic hunter-gatherers across the North China and further to the Tibetan Plateau had several stages and was obviously impacted by climate changes. As the earliest microlithic site on the TP, JJF02 has played a key role in the microlithic hunter-gatherers' spread to the Tibetan Plateau and their successful adaptation to the high-altitude environments indicated by their subsequent wide and intensive occupation of almost the entire plateau.

CT scan as a tool to unravel the dynamic of Mediterranean Coralligenous

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Coralligenous reefs, made up of crustose coralline algae (CCA), represent an important ecosystem of the Mediterranean shelf. The skeletal framework of these bioconstructions hosts a variety of organisms, many of which compete for the space while contributing to the reef growth, while others weaken the structure through their bio-erosive activities. The relationships between builders, destroyers and inhabitants remain elusive. We collected two discrete Coralligenous build-ups off the Marzamemi Coast (South-East Sicily). The first (CBR2_3_7c, 37 m depth) was collected in an area with high Coralligenous cover, and the second (CBR2_4_21c, 36 m depth) from a submarine channel with sparsely distributed build-ups. A Computed-Tomography scan was used for the first time with Coralligenous to reconstruct the internal structure of the two build-ups. Additionally, radiocarbon dating on the two build-ups has been used to determine their age and growth rate. Results show a complex behavior of the Coralligenous inner structure. The framework can be divided into four main density categories (Low, Medium, High and Ultra High), which are associated with different skeletal carbonates and the sediment infills. The structure cavities, either primary or due to taphonomic processes, have been measured as porosity. In the CBR2_3_7c, we observe that the HD material associated with compactly overgrown algal thalli generally decreases from bottom to top, accompanied by an increase in porosity. The CBR2_4_21c, seems instead to show higher percentages of HD material on its top and a counterintuitively high porosity at the bottom of the structure, possibly reflecting an intense bioerosion activity. In both samples the highly resolved analysis points to a non-linear growth of the build-ups. Microfacies observations confirm the tomographic data, revealing denser skeletal/micrite textures associated with the HD material, while more porous and less cemented structures are reflective of the LD and MD materials. With increased porosity, the micrite infills reduce in abundance leaving the support of the framework to the CCA. The understanding of the differences, in terms of structural density, porosity and growth rate, of the two structures might shed a light on the influence of the extremely local environment on the Coralligenous growth and inception.

Skeletons vs micrite in building the framework of the present-day Coralligenous along the Marzamemi coast (Sicily)

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The Mediterranean Sea hosts several coralligenous build-up rising from the sedimentary bottom. They are characterized by heterogenous benthic assemblages. In the frame of the project FISR_04543 “CRESCIBLUREEF”, the coralligenous bioconstructions formed along the Mediterranean shelf in front of the Marzamemi village (Sicily, Italy) have been studied to investigate the nature and role of micritic sediments in the growth and stabilization of the bio-structures. For microfacies analysis, thin sections have been examined using transmitted and UV-light. The microfacies revealed a high vacuolar algal skeletal framework with several other organisms' remains (bryozoans, serpulids, echinoids, foraminifers, ostracods, and sponge spicules) and cavities filled with different types of sediments, notably autochthonous and allochthonous micrite. A preliminary point counting, performed on polished thin sections, showed the predominance of calcareous red algae (up to 50.7%) followed by allochthonous micrite (22.3%), empty cavities (13.2%), other bioclasts (4.2%), autochthonous micrite (4.1%), bryozoans (3.4%), serpulids (1.5%), and endolytic sponges (0.6%).

The autochthonous micrite shows peloidal or aphanitic textures, whereas allochthonous micrite (detrital organic and inorganic micrite) shows a denser texture rich in small skeletal and non-skeletal grains. The autochthonous fraction is made of very fine anhedral to sub-euhedral calcite crystals and it is associated with the presence of sponge spicules. Moreover, this fraction shows a bright fluorescence when excited with UV-light suggesting a high content in organic matter. These findings suggest that a double type of organics might be present in the autochthonous micrite: a type trapped among the crystals and a type strictly related to the organic nucleation of the crystals and preserved inside their lattice. On the contrary, the allochthonous fraction displays a very faint to none epifluorescence, testifying only a few amount of sedimentary organic matter trapped among the fine grains of this fraction.

It could be assumed that the autochthonous micrite is formed *in situ* through organomineralization processes of the sponges' soft-tissues and occurs during the formation of the skeletal framework, whereas the allochthonous fraction derives from physical processes including the entrapment of skeletal remains of species living on and inside the coralligenous build-up, this latter taking place after the development of the primary framework.

Low reef coral diversity in the incipient Red Sea (Burdigalian, Saudi Arabia)

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In the Tertiary, temperatures and pCO_2 dropped from high levels of the late Mesozoic to present-day levels, with a plateau in the Burdigalian to Langhian (Lower to Middle Miocene). During the Miocene, scleractinian coral reefs developed into the euphotic ecosystems known from the present-day tropical and subtropical shallow-waters. Coral diversity peaked in the Burdigalian, and declined afterwards. In contrast to this global trend, scleractinian diversity was low in the Red Sea which had only started to open in the Oligocene, and experienced its first marine incursion in the Burdigalian. Here, we report on the hard coral diversity of Miocene reefs assigned to the Burdigalian Wadi Waqb Member (Jabal Kibrit Formation) from outcrops behind the Red Sea coastline near Umluj, Saudi Arabia. Our study confirms that at that time, coral assemblages in the Red Sea were similar to those in the Mediterranean but different from the Indo-Pacific, with the notable exception of the genus *Porites*, being present in both, the Mediterranean and the Indo-Pacific. The observed faunistic differences in the coral dominated benthic assemblages are consistent with the hypothesis that the Afar mantle plume was blocking the connection between the Red Sea and the Indo-Pacific from the Early Oligocene to the Pliocene, while the Red Sea was connected to the Mediterranean through the Gulf of Suez. This blockage may have thus impaired exchange of scleractinian coral species with the Indo-Pacific. Moreover, in addition to the scleractinian diversity survey, we here present a first taxonomic assessment of other relevant reef-dwelling organisms such as coralline algae and benthic foramnifers and provide a comparison to modern day species spectra of coral reefs in the Red Sea.

Fossil coral reef terraces as paleo sea-level indicators since the Quaternary: Records from the Philippines

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Coral reef terraces are planar geomorphological sea-level indicators, normally observed along coastal areas, that are formed through repeated bioconstructional and erosional processes. Following our previous work in which we produced a standardized database of Last Interglacial (LIG) sea-level indicators in Southeast Asia, we revisited a site in the Philippines where inferred fossil coral reef terraces were previously reported. Based on previous studies, Late Pleistocene coral reef terraces (rising to about 100-155 meters above mean sea level (m amsl) and Holocene terraces (rising to about 14 m amsl) in age are observed along the western coast of Pangasinan, west Luzon Island. In this work, we present new geomorphic and stratigraphic data on the fossil coral reef terraces in Pangasinan, west Luzon which adds to the limited LIG sea-level indicators in the region. We conducted Real-Time Kinematic Global Navigation Satellite System (RTK-GNSS) surveys along select areas in western Pangasinan to provide precise elevations and geographic locations of these fossil sea-level indicators. We also analyzed available Interferometric Synthetic Aperture Radar (IfSAR)-derived digital elevation models to map and delineate the elevation patterns of these raised coral reef terraces. Based on our analysis, we identified distinct levels of coral reef terraces which may correspond to several episodes of RSL change from the late Quaternary to the present. Analysis of sea-level indicators is important in constraining both regional and global drivers of sea-level change. However, our work proves to be more challenging due to the difficulties of finding pristine dateable materials for radiometric dating and doing field surveys during a global pandemic. Nonetheless, we hope that data from this research will help us further understand the different drivers of past sea-level changes in SE Asia providing necessary geologic baseline data for projections of sea-level change in the future.

The growth of Sabellaria spinulosa bioconstructions in tank experiments

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Sabellaria spinulosa (Leukhart, 1849) is a polychaete suspension feeder worm that lives in tubes consisting of agglutinated sediment particles held together by a very resistant sticky substance produced by the worm itself. Each individual lives inside the tube he builds, the tubes juxtaposed one another trap additional sediment and give rise to imposing structures that change the backdrop on which they are established. These worms are gregarious organisms able to build bioconstructions known as worm reefs that can contain several thousand of tubes. The worm reefs are present at all latitudes with various genera. The genus Sabellaria is widespread along the North Atlantic European coast and also along the Mediterranean coasts. In the present work, some fragments sampled from the Torre Mileto reef (Apulia, Italy) have been used to set up experiments of tube growth in tanks under controlled conditions (temperature, salinity, pH, turbulence, amount of nutrients, etc.). Three different kinds of sands were used in tanks, in order to understand how Sabellaria selects sediment granules according to their mineral-petrographic composition, shape, size and density. The effect of grain-size on the reef growth were analyzed varying the granulometric range of sands used in the experiments (125-355 μm). The results obtained are of great interest for the understanding of the natural dynamics of the worm reefs in situ.

Historical models of Iranian culture atlas

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1. ministry cultural heritage

Iran in the early Paleolithic period From three million two hundred thousand years ago The first human signs discovered until about two hundred thousand years ago It can be considered the beginning of the Paleolithic period. One of the most important findings of prehistoric mankind was the use of fire. Containment and use of fire probably It was realized about a million years ago. In the early Paleolithic period, humans through hunting and gathering plants from the surrounding environment, lived their lives, They lived in natural shelters such as caves And they used very simple stone tools in their daily work. Not many findings have been obtained from the early Paleolithic period. In Iran, the oldest human remains in Khorasan river discovery bed has been discovered. Also, in Ganj Par Rostam Abad, Shiv To Mahabad, Darband Cave, Gilan. south and east of Tabriz, Ladiz, 65 km south of Zahedan, Around Khwaja Sistan mountain, Helilan narrow bridge and some scattered places of human settlements It was discovered in the early Paleolithic period. The tools of this period are called Asholi tools. It should be noted that at that time Central Asia had a milder climate And many rivers and lakes were seen in the region. For example, the Persian Gulf continued until near Mosul And there were many lakes in the center of the Iranian plateau It is possible to see the current small lakes of Iran, such as Lake Urmia, He considered Qom, Ni Riz and Hamon to be remnants of the waters of that era . Fossils of many sea creatures from these seas It is left in Central Alborz.The oldest works of this period in Iran belong to The lower Paleolithic period is New And it is between 200,000 and 100,000 years old. Iran has received attention in the New Paleolithic era in which small groups lived in the corners This period has been divided into three parts: lower, middle and upper. New Paleolithic era in which small groups lived in the corners This period has been divided into three parts: lower, middle and upperMiddle Paleolithic

Palaeoecological Reconstruction of the Flora, Vegetation, Landscape and Palaeoethnobotany at the remarkable Late Palaeolithic / Early Mesolithic Rock Shelter of Flözerbändli (Muota Valley, Canton of Schwyz, Switzerland)

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Palaeoecological analyses of Palaeolithic and Mesolithic archaeological sites are relatively rare for Central Europe. Here we present palynological, macro-botanical and charcoal determination results for the anthropogenic rock shelter frequentation between ca. 10300 and 8400 BC in the context of the exploitation and use of plants by prehistorical hunter-gatherer societies. This remarkable abri of Flözerbändli is famous for its unique and decorated antler fragment from the Epi-Palaeolithic (radiocarbon dated to 10,519-10,028 BC), which was decorated with rows of pit marks probably using a flint tool. During the Epi-Palaeolithic and Early Mesolithic, the local arboreal vegetation consisted of pine, birch, juniper, alder, lime and hazelnut. Collected hazelnuts were used as nutritious and staple food as revealed by the regular occurrence of hazel nutshell parts in the archaeological layers of the Flözerbändli rock shelter. In addition, the stratigraphy of the abri contained some charred seeds of herbs, such as from Caryophyllaceae and from St. John's wort (*Hypericum* cf. *perforatum*), which is remarkable, as the latter plant is known as a remedy for medicinal purposes until today. Considering the maturity of most of the palaeoethnobotanical finds, the rock shelter was predominantly used during the summer or autumn months. Interestingly, yew wood (*Taxus baccata*) was used as firewood in the rock shelter as revealed by abundant charcoal finds, eventually taking advantage, that this wood is relatively smoke-free when burnt. Eventually, the charcoal remnants may be the result of extracting yew poison from fresh twigs in order to lubricate the arrows of the prehistoric hunters. The palynological context confirmed the Younger Dryas and Early Holocene vegetation to be expected in a central Alpine valley at 740 m a.s.l. for that time. However, algae remains such as from *Trachelomonas* and *Mougeotia*, which both occur in stagnant water, do point to the transport of water to the rock shelter, which in terms of water was, and is, an extremely dry living spot since the Epi-Palaeolithic.

Poster - sessions 37, 52, 72, 158

A palaeo-reconstruction of Devensian ice-flow phasing in the Vale of York.

Ms. Holly Jenkins [1], *Dr. Bethan Davies* [2]

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Ice provenance and dynamic behaviour between the British-Irish ice sheet has been subject to controversy in recent years. Several studies of clast lithology and glacial morphology have alluded to the inland extension of the North Sea Lobe into north-east England and the Vale of York. However, the extent that the North Sea Lobe extends into the Vale of York, and its dynamic interactions with the Stainmore and Wensleydale ice masses is as yet unknown. This study aims to reconstruct the complex provenance of the Vale of York ice lobe through clast lithological and matrix geochemical analysis. Multivariate statistical methods were applied to the datasets in the form of a PCA and Cluster Analysis, to aid in the correlation of Vale of York tills to BIIS and NSL type sites. Indicator erratics for NSL (Cheviot volcanics and flint), Scottish (greywacke and metasedimentary lithologies), and Lake District (felsic tuff) provenance were found in several tills and were central to tracing till provenance. Major and trace metal, and clast lithological cluster analyses have identified at least two occasion where the NSL and Eden-Stainmore ice converges at Scorton Quarry in the north of the Vale of York. NSL ice has been traced as far south and west as Norton Mills. Deposits to the west (Marfield Quarry and Lightwater Quarry) are dominated by a local Wensleydale ice signature and lack evidence of North Sea ice.

Insights into the longterm behavior of North American ice sheets from newly identified Middle Pleistocene Margins

Mr. Phillip Kerr [1]

1. Iowa Geological Survey

Newly identified Middle Pleistocene glacial boundaries and ice flow indicators have been delineated in the Midwestern United States using a novel drainage network analysis. The glaciated region beyond the last two glacial maxima is tectonically stable, and the topography is dominated by a thick package of glacial sediments deposited throughout the Quaternary. As this landscape was created by continental ice, the last ice advance covering an area would be the primary driver for drainage organization. This morphology would largely persist until burial during subsequent glacial episodes. By inverse, the modern drainage network is a palimpsest record of previous glacial advances.

To create a model identifying indicators of glacial advances within drainage networks, this study mapped moraines, meltwater flow paths, and current drainages within two younger ice lobes: the Des Moines and Illinois lobes. The ~MIS 2 Des Moines Lobe flowed south into central Iowa and disrupted the headwaters of basins. In contrast, the MIS 6 Illinois Lobe advanced westward into southeastern Iowa which blocked and dammed the lower reaches of watersheds. These findings show the newly formed drainage network is not deranged but is in fact highly organized due to glacial landforms; both ice advances imprinted their lobate silhouette across basins, leaving a moraine-derived, trellis-pattern network.

Using these diagnostic patterns on the older landscape, a series of northern- and eastern-sourced lobes were identified, and their cross-cutting relationships were used to establish their relative age. These analyses indicate that at least four lobes advanced from central Canada and two-to-three flowed out of the Great Lakes Region during the Middle Pleistocene. Additionally, all ice avoided southwestern Wisconsin. Older, northern advances appear to have been buried by eastern lobes, suggesting a shift in the Middle Pleistocene that caused ice in eastern Canada to extend further south. These new margins represent the first step in an effort to build a new terrestrial-based framework for the behavior of the Laurentide Ice Sheet throughout the Early and Middle Pleistocene. These findings can inform numerical models dealing with previous iterations of the Laurentide Ice Sheet and will guide future work unraveling the Midwest’s complex glacial sediment package.

Determining the retreat chronology of the Green Bay Lobe, Wisconsin, USA during the last deglaciation using cosmogenic nuclides from exposed bedrock

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A precise chronology of ice sheet retreat during the last deglaciation is important for evaluating how paleoclimate, sea level, and ice sheet dynamics co-evolve during past periods of rapid warming. This information is necessary to constrain what climatic triggers lead to rapid deglaciation, which advances understanding of modern ice sheets experiencing similar rapid warming today. Deglacial chronologies of the Laurentide Ice Sheet retreat are based on radiocarbon dating of organic matter and cosmogenic nuclide dating of moraine boulders, but existing data has numerous spatial and temporal gaps that complicate interpretations of ice sheet retreat and its relation to global sea level and climatic triggers. The Green Bay Lobe was a major lobe of the southern Laurentide Ice Sheet, but material suitable for radiocarbon dating is sparse possibly because of permafrost conditions in the region. Here, we test and add to the existing deglacial chronology of a major lobe of the southern Laurentide Ice Sheet (Green Bay Lobe, Wisconsin) using *in situ* cosmogenic radionuclide dating (^{10}Be and ^{14}C in quartz) collected from glacially eroded bedrock promontories and glacial erratic boulders located between major moraine sets. We present new cosmogenic nuclide dates spanning a 175 km north-south transect of the Green Bay Lobe. These data will fill spatial and temporal gaps in the Green Bay Lobe retreat chronology and test whether previous relative or correlative dating assumptions based on moraines and till stratigraphy are accurate. Paired cosmogenic nuclides (^{14}C and ^{10}Be) will also allow inference of rates of subglacial erosion on bedrock outcrops during the last glacial period.

A chronological database from Greenland - GreenDated

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GreenDated aims to compile and assess all published radiocarbon, optically stimulated luminescence (OSL) and cosmogenic isotope dates from Greenland. Our goal is to make an open-access database and use the information to make a well-constrained deglaciation chronology of the Greenland Ice Sheet the last c. 20 ka. Previous attempts have compiled some of the exciting data (e.g. Dyke et al., 2002; Sinclair et al., 2016); others have been focusing on a sub-set of the data for example by compiling the oldest dates at the outer coast and close to the present ice margin extent (Bennike & Björck, 2002; Funder et al., 2011). In this compilation, we use a similar protocol as the DATED-1 database from Eurasia (Hughes et al., 2015) and the SvalHolo database from Svalbard (Farnsworth et al., 2020). Until now, we have compiled >5000 ^{14}C from c. 600 papers, and >1000 ^{10}Be dates from c. 100 papers. We have so far not compiled the OSL dates but estimate that there are <200 dates in c. 30 papers. The plan is to compile all published data with a cut-off date ultimo 2022 and make them available ultimo 2023.

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The deglacial behaviour of the Northeast Greenland ice stream and 79N ice shelf.

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This project focuses on the Northeast Greenland Ice Stream (NEGIS), a key sector of the Greenland ice sheet (GrIS) because it controls ice flux into the NE Atlantic (an area sensitive to freshwater input) and holds a sea-level equivalent (SLE) of ~1.4m. This sector of the ice sheet is known to have undergone dramatic retreat during the Holocene Thermal Maximum (HTM) and is predicted to be vulnerable to future climatic changes. This work aims to reconstruct the past behaviour of the NEGIS and understand ice/ocean/atmosphere feedbacks over 100 - 1000yr timescales.

Along 79N fjord during the last Glacial Maximum (LGM) the NEGIS was coalescent with local ice caps, with warm-based ice operating up to ~850m asl. The earliest exposure age constraints for the initiation of ice stream thinning are 23 - 20 ka and this is concomitant with grounding line retreat from the outer continental shelf edge at ~19.5 ka. Continued retreat of the ice to the mid-shelf by ~ 15 ka is matched by onshore thinning between 18 – 15ka. The development of a pronounced grounding zone wedge complex in the mid Norske trough can be dated to ~15 - 13 ka and this temporary stability is manifest onshore in a staircase of perched delta and lateral moraines that mark a reduction in the ice stream thinning rate around 12.5ka.

The NEGIS retreated through the inner continental shelf between 12 – 10 ka and was pinned at the eastern end of 79N fjord by 9.2 ka. The ice stream then calved rapidly between 9.2 and 8.0 ka due to marine ice sheet instability into deep water. This led to a period of open marine conditions in 79N fjord during the Holocene Thermal Maximum. However, post ~4.5 ka Neoglacial cooling triggered ice stream/shelf regrowth and the cessation of marine conditions. The rapid retreat of the ice stream and disappearance of the 79N ice shelf at the opening of the Holocene due to increased air and ocean temperatures will be mirrored in future decades as we move into a + 2°C world.

Was there an ice shelf on Baffin Bay during the Last Glacial Maximum?

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Ice shelves are floating ice platforms extending beyond grounded ice sheets on continental margins. They play a major role in the stability and mass-balance of marine-terminating ice sheets by acting as buttresses that restrain rapid ice flow and loss of ice to the ocean. The glaciological significance of ice shelves is relatively well established for the stability of modern ice sheets of Antarctica. Past ice shelves of the Arctic, however, are poorly documented while their role for the stability of former ice sheets remains mostly unknown. The existence of an ice shelf in Baffin Bay during the last glacial episode has recently been suggested and debated, but this hypothesis has remained inconclusive due to the absence of physical evidence. Here we present swath bathymetry and seismostratigraphic data that reveal a large moraine system extending along the continental slope off Baffin Island independently from glaciers grounded on the outer shelf, demonstrating that a 500-m thick ice shelf covered northern Baffin Bay during the last glacial episode. This ice shelf likely had a profound impact on the stability of a series of major ice streams that drained the interior of the Laurentide, Innuitian and Greenland ice sheets. Climate warming and global sea-level rise in the early stage of deglaciation possibly contributed to a large-scale collapse of the ice shelf, removing the buttressing effect which led to the destabilisation and reorganisation of tributary ice streams from these three ice sheets. These findings support the idea that ice sheets around northern Baffin Bay did not contribute significantly to rising sea level before Meltwater Pulse 1A (MWP-1A – 14,650 years ago).

MIS 3 records of ice sheet history and climate change in northern Sweden

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In the central parts of northern Sweden, a relict pre-Late Weichselian landscape has been preserved due to frozen-bed conditions of the last ice sheet covering the area. Characteristic of this landscape is eskers and drumlins showing ice flow from the NW and Veiki moraine, a type of ice-walled lake plains formed due to melting of debris covered stagnant ice. Earlier studies have shown that the preserved landforms are from the Weichselian glacial period, however, which stadial/interstadial phase they belong to has been debated. We have studied sedimentary records from the relict landscape with the aim to date the glacial history and improve earlier studies of Weichselian interstadial climate and vegetation. Methods used are OSL-dating, radiocarbon dating, pollen analysis, macrofossil identification and stable isotope analysis of leaf waxes. Our OSL-dates of the Veiki landscape give ages of 56-39 ka which implies that the moraine was formed during MIS 3. Since the Veiki landscape was formed due to down wasting of stagnant ice at the easternmost margin of an ice sheet in central northern Sweden, the ages are evidence of a phase where we had an intermediate-sized ice sheet in Scandinavia. Through comparisons with other data on glacial history and climate we suggest that the ice sheet advance prior to Veiki moraine formation occurred during Greenland stadials 16.1-15.1 (56.5-54.2 ka) and that final melting of the ice within the landscape took place during GI-14 (54.2-48.3 ka). Pollen, macrofossils and leaf wax stable isotope data give additional information about the interstadial conditions. We analysed d^2H_{wax} from the sites Riipiharju and Rauvospakka and observe that the clear climatic shift from cold to warm conditions reflected in the pollen signal in the Riipiharju sequence is also reflected as a change in the isotope data. For Rauvospakka the isotope data indicate more climatic variability than inferred by the pollen data.

Did the Roone ice shelf suddenly retreat during the Last Glacial-Interglacial Transition?

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Recent modelling studies suggest significant mass loss and rapid collapse of the West Antarctic Ice Sheet (WAIS) has occurred in the past, making recent predictions that anthropogenic warming could lead to a loss of the WAIS in the next few centuries particularly alarming. However, major uncertainties exist regarding the past and future stability of the WAIS and its ice shelves. To better predict the fate of the WAIS under future warming scenarios, we must first determine how stable is the ice sheet and its ice shelves in response to forcings. This can be achieved using accurate paleoclimatic records during past climate transitions.

The Last Glacial-Interglacial Transition (LGIT), 20,000-6,000 years ago, is an ideal period to assess the relationship between climate, ice sheets and sea level. During this period, the temperature in Antarctica increased by over 11° Celsius and the global mean sea level rose 125-130 meters. Marine sediment records suggest the Ronne ice shelf, the second largest ice shelf in Antarctica, presented considerable retreats in response to the changing environmental conditions. Despite the global relevance, to date, the magnitude and timing of these retreats are still uncertain.

Here, we present a centennial resolution diatom record from the Skytrain ice core during the LGIT. The diatom diversity in Antarctic ice cores closely represents the proximity of the nearest open water source. Antarctic coastal domes present diatom assemblages dominated by locally sourced sea ice species. This contrasts with the diatom diversity observed at inland sites, which are dominated by open ocean species indicating long-range transport. We use these characteristic signatures to track past changes in the proximity of the nearest open water source, providing new evidence to explore the potential sudden retreat of the WAIS during the LGIT, causes and timing.

Quaternary stratigraphy and glacial history at Peace River, Alberta: Implications for mapping and modeling of older continental ice sheet limits in western Canada

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The number and style of the continental Laurentide Ice Sheet (LIS) glacial advances in the western prairies of North America has been the subject of debate, especially in the Peace River district of western Alberta and eastern British Columbia. Given its northern Alberta location, resolving the glacial record of this area has important implications for understanding the evolution of the LIS, especially during its earlier (pre-Late Wisconsin) phases. The Quaternary stratigraphy documented in Alberta's Peace River lowlands has been subject to conflicting interpretations. This is probably due to the absence of a single complete stratigraphic sequence preserved at any one section (reflecting extensive landsliding along the Peace River valley), and a lack of chronologic control for lower parts of the sequence.

The valley-fill sediments located at the confluence of the Heart and Peace rivers, within the town of Peace River, Alberta, provide perhaps the best record in the Interior Plains of western Canada of an almost continuous sequence of Quaternary sedimentation extending from the bedrock surface to present. Here, a 187 m thick composite stratigraphy records the transition from preglacial fluvial sedimentation (Unit 1), to a penultimate proglacial sedimentary sequence (Units 2 and 3) that is conformably overlain by interstadial fluvial sediments (Unit 4) of possible MIS-3 age, or older (based on limiting radiocarbon dates). In turn, these sediments are overlain by a Late Wisconsin ice advance/retreat cycle of sedimentation from the LIS (Units 5-8). The sequence is capped with Holocene loess with paleosols, containing mollusc and plant macrofossils. The only till unit in the stratigraphy (Unit 7) is from the Late Wisconsin glacial advance. Clasts of Canadian Shield lithologies in the lower fluvial sediments (Unit 2) are derived from southwestward draining southern Buffalo Head Hills catchments, where multiple, older glacial sediments have been documented. Consequently, we argue that there is evidence for only a single continental (Laurentide) glaciation in the eastern Peace River district, similar to what is defined to the southwest in Quaternary exposures along the Smoky River.

Late Quaternary glacial history of the Sjuøyane archipelago, northern Svalbard

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Sjuøyane are the northernmost islands of the Svalbard archipelago. Little is known about their glaciation and relative sea-level history, deglaciation, and postglacial environments. Here we present preliminary results from two Quaternary geological field expeditions to Sjuøyane and discuss challenges and potentials. We also present new cosmogenic exposure ages of bedrock and boulders to reconstruct the timing of the last deglaciation. The ultimate goal of this study is to better understand the history and behavior of the northern margin of the Weichselian Svalbard-Barents Sea Ice Sheet. Being the northernmost land area on Svalbard, Sjuøyane are strategically well located for this purpose.

Coastal sedimentary sections along several of the islands provide insight into the Weichselian and Holocene stratigraphy. We identified two coarsening-upwards marine sedimentary sequences. Previous studies have interpreted these sediments as evidence of a pre-Late Weichselian and a Late Weichselian glaciation. Our radiocarbon and luminescence ages indicate a glacier advance before ~40 ka.

The postglacial marine limit sits at 18 m a.h.t. in Isflakbukta, Phippsøya (one of the islands). Above that, we identified an upper pre-Last Glacial Maximum marine limit marked by a clear bedrock erosional notch with wave-eroded bedrock, large water-worn boulders, and rounded cobbles. Ages from raised beaches and deltaic sediments at Parryøya (one of the islands) suggest that the island was ice free at *c.* 11.2±0.3 cal. ka BP.

Stratigraphic reconstruction of the lower/middle Pleistocene transition in the western sector of the Garda end-moraine system

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The Lake Garda region in Northern Italy hosted repeated glaciations by the Adige-Sarca glacier during the Pleistocene, forming Lake Garda, the Garda end-moraine system, and an extensive suite of glacial and glaciofluvial deposits. Late Alpine tectonic activity uplifted the area west of present Lake Garda over the course of the Pleistocene, shifting subsequent glacier advances eastward. Reconstructing the timeline and extent of earlier glacier advances in the western Garda end-moraine system has been made difficult by the limited availability of exposures and challenges in determining absolute ages for pre-Last Glacial Maximum deposits. This study sets out to constrain the absolute timing of glacial and glaciofluvial deposits at two sites in the western Garda end-moraine system, the Calcinato Moraine and Ciliverghe Hill. A cut-and-cover railway construction project briefly exposed a succession of Pleistocene deposits at both the Calcinato Moraine and Ciliverghe Hill in the spring of 2022, allowing for detailed stratigraphic description and sampling of crystalline clasts from the exposed units for isochron-burial $^{26}Al/^{10}Be$ dating. Prior paleomagnetic investigations indicates the basal units of the exposed successions may be in the range of MIS 22 – MIS 16 in age. The results of isochron-burial dating of these briefly exposed sediments may potentially provide an independent temporal constraint for paleomagnetic data, building upon current research projects examining deposits from the early Pleistocene in the western Garda end-moraine system, with the possibility to contribute significantly to our understanding of past glaciations and interglacial periods in the Southern Alps.

Early Middle Pleistocene glaciations and interglacials in Poland

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The lower boundary of the Mid-Pleistocene is identified, based on magnetostratigraphic examination of deposits at 3 sites, namely Kończyce and Kozi Grzbiet in southern Poland and Kalejty in northeastern Poland. Generally, the early Mid-Pleistocene (MIS 19-12) consists of 2 interglacials and 2 glaciations in Poland. A sequence of these stratigraphical units starts within the complex Podlasian Interglacial (Cromerian I-II), interglacial optima of which correspond presumably to MIS 21, 19 and 17, and they are separated by cool intervals of MIS 20 and 18. A maximum extension of the early Mid-Pleistocene glaciations and the age of the first one are represented by a till and the admixture of the Scandinavian material in fluvial deposits in proglacial valleys, in southern Poland located in front of the advancing ice sheet. Such deposits exotic material are traditionally named the mixed gravels. The Sanian 1 Glaciation (Donian?) was the most extensive in Poland and during its maximum, the ice sheet overpassed a latitudinal river valley located along the northern margin of the Carpathians and then running through the Dniester valley to the Black Sea. This fore-Carpathian river was reactivated after the Sanian 1 Glaciation, being active during the following Ferdynandovian Interglacial (Cromerian III-IV) that has been previously correlated with MIS 15-13 but at present, it is considered to be mostly the equivalent of MIS 15. The ice sheet of the next, Sanian 2 Glaciation (Elsterian), occupied a limited area and its extension was presumably similar to the Odranian Glaciation (Saalian) of the late Mid-Pleistocene. The research was done within the project no. 2017/27/B/ST10/00165, funded by the National Science Centre in Poland.

Pedostratigraphy of the Baluchabad loess-paleosol sequence, Northern Iran

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The early to middle Pleistocene climate changes and global cold and warm stages remain widely unknown in northeast Iran. Mainly due to the paucity of regional sedimentary records the early to middle Pleistocene climate changes and global cold and warm stages remain unknown in northeast Iran. Loess deposits are one of the sedimentary archives that well-preserved information about paleoclimatic changes. The loess-paleosol sequence (LPS) of Baluchabad is located at the north face of Alborz Mountain and contains twelve paleosols with varying weathering degrees that are well distinguishable by their clear boundaries from loess layers. The detailed study of the 54 m-long sequences has a high potential to reconstruct the paleoenvironmental conditions in the area. According to the results of the field description, grain size distribution, and magnetic susceptibility the section has been divided into 4 units. Unit 1 is from top to 20.4 m depth under the land surface and starts with a weakly developed soil (U1S1) identified by a slightly darker color and a weak subangular blocky structure. Among other notable points of this unit is the existence of 3 layers with a higher amount of coarse silt and sand at the depths of 10, 14, and 18 m. Unit 2 is from 20.4 to 34 m depth and contains five paleosols separated by compacted loess layers related to MIS-5 with different degrees of weathering from weak to well-developed pedocomplexes, respectively. Unit 3 from 35-47.7 m below the surface and unit 4 contains 3 well-developed paleosols intercalated with loess layer and sharp upper and lower boundaries making it clearly distinguishable from loess layers. The reddish-brown color of these paleosols, the high percentage of clay content, and the underlying Bk horizons indicate an advanced stage of development of these paleosols. Also in unit 4 existence of iron and manganese (hydr-) oxides demonstrate well-developed paleosols formed under reducing conditions. Generally, the Baluchabad section provides a unique framework for regional and superregional stratigraphy correlation and investigating in detail paleoenvironmental changes during the middle to early Pleistocene.

Establishing the timing of the first Fennoscandian ice sheet advances on the North European Plain

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The Fennoscandian ice sheet (FIS) repeatedly advanced from the Scandes Mountains, with its first inception in the late Pliocene. During major glaciations of the Middle-Late Pleistocene, it coalesced fully with the British-Irish and Barents-Kara Sea ice sheets, forming the core of a singular Eurasian Ice Sheet Complex. Maximal configurations, documented by an asynchronous and discontinuous sedimentary record, depict the FIS extending east from the Dutch Rhine-Meuse delta, fringing the Harz Mountains and Thuringian Uplands in central Germany, and abutting the northern slopes of the Sudeten and Carpathian ranges in southern Poland. Multiple advances throughout the Quaternary inundated the North European Plain (NEP), rerouting major south-north drainages. While these patterns have been considered in detail for the Last Glacial Cycle (LGC), empirical reconstructions of the FIS for earlier Pleistocene glacial periods remain poorly constrained, relying on stratigraphic correlations from palaeoenvironmental data over timescales beyond reach of most conventional geochronometers.

The ^{26}Al-^{10}Be cosmogenic nuclide (CN) pair in quartz provides a well-understood framework for dating glacial deposits across timescales of 10^5-10^6 years. In North America, recent CN applications have bolstered insights into the pre-LGC glaciations, uncovering broader spatial extents for the earliest Pleistocene Cordilleran and Laurentide ice sheets. Although a significant volume of glacigenic material distributed over the NEP has also been speculated to support ages of ≥MIS 12 (478-424 ka), additional scrutiny of the chronologies is warranted in many cases.

Here, we attempt to regionally correlate the earliest glacial strata on the NEP, and link these to a consistent chronology by employing a CN burial dating approach capable of resolving depositional ages up to ~5 Ma. This strategy invokes a source-to-sink framework, coupling inverse Monte Carlo simulation of CN abundances with a rejection sampling module, enabling probabilistic burial-age determination for samples characterized by complex exposure and erosion rate histories which are prevalent within glaciated catchments. Our field sites, spanning locations between the Netherlands and Lithuania, allow for a wide range of potential early FIS geometries. It is anticipated that new quantitative ages bracketing pre-Late Pleistocene chronozones in this region will improve the utility of non-absolute, yet widely-applied, bio- and palynostratigraphic correlation schemes.

Important findings from the TephroMed project III: The cryptotephras of the ICDP Dead Sea deep core during the last 130kya

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The eastern Mediterranean region has experienced large hydroclimatic shifts throughout the last glacial to glacial period (130-30kya). The region is located between the contrasting humid Mediterranean climate and the Saharo-Arabian desert belt. Important sedimentary archives from lakes allows past changes in precipitation regimes to be reconstructed using multiple proxies. The Dead Sea (Israel) ICDP DSDDP record is an important palaeoenvironmental archive that provides detailed insight into the environmental characteristics and timing of these climatic shifts. This record has undergone extensive palaeoenvironmental and climatic reconstructions (e.g. stable isotopes, pollen) and has been dated through absolute and relative methods (radiocarbon, U-Th, wiggle-matching). However, problems with large chronological uncertainties have prevented detailed insight into the regional climatic (a)synchronies with other palaeoclimatic records in the region (e.g. Lake Van, eastern Anatolia).

The application of cryptotephra (non-visible volcanic ash), is a powerful chronological tool to refine age uncertainty and correlate palaeoclimatic records together, particularly over vast distances. Previous investigations on The Dead Sea record have found important cryptotephra layers within the sediment (e.g. the early Holocene S1 tephra), allowing palaeoenvironmental records to be integrated.

Building upon this work, we present here the important cryptotephra findings from the Dead Sea, part of the TephroMed project. Our cryptotephra investigations focused on intervals of the record that possibly contained glass shards from important eruptions originating from volcanic sources in the Mediterranean region. Numerous tephra layers have been identified. Major, minor and trace element volcanic glass chemistry (Electron microprobe analysis and LA-ICP-MS), with the use of statistical methods, have revealed cryptotephra layers derived from numerous volcanic sources in the Mediterranean. These include Central Anatolia and Eastern Anatolia, Hellenic Arc and the Italian volcanoes. The identification of cryptotephra in the Dead Sea has greatly extended the tephrostratigraphic framework of the region of disparate volcanic regions. Correlations using tephra layers have now been made to other important palaeoenvironmental sites (Lake Van) and archaeological records in the region, including into the Levant and Arabia. This has provided insight into the time transgressive nature of climatic shifts throughout this period.

Volcanic reconstruction of the Belbaşhanı Pumice eruption: a late Quaternary fallout deposit emitted in the Central Anatolian Volcanic Province (CAVP), Turkey

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The Central Anatolian Volcanic Province (CAVP), which is related to post-collisional volcanism, has hosted many volcanic events in central Turkey since the Miocene to the present day. The most prominent are the Cappadocian ignimbrites, which cover an area of 20000 km^2 and had been formed between ca. 10 and 2.5 Ma. Since the early Quaternary, the eruptive activity has been concentrated both in basaltic monogenetic volcanic fields and large felsic polygenetic complexes, including Acıgöl caldera, Erciyes, and Hasandağ stratovolcanoes (i.e., the most active, explosive, and dangerous composite volcanoes within the CAVP). Hasandağ volcano, which currently has risen seismic and fumarolic activity, has produced large explosive eruptions during the last million years, in conjunction with several caldera collapses. The pyroclastic deposits formed by Hasandağ comprise ignimbrites, block and ash flows, pumice and ash fall deposits. One of these is the Belbaşhanı Pumice deposit, which age has been estimated at 339± 50 ka by U/Pb dating on zircons and is going to be re-evaluated by Ar/Ar. Belbaşhanı Pumice is a thick fallout deposit, which is well-preserved along the Belbaşhanı valley, located between the eastern flank of Hasandağ and Keçiboyduran volcano. In this work, we have investigated in detail the tephrostratigraphy, deposit distribution, granulometry, glass geochemistry, geochronology, and volcanic ash morphological properties of the Belbaşhanı Pumice aiming at reconstructing isopach/isopleth maps and the physical parameters of the related explosive eruption (i.e., erupted magma volume, column height, tephra distribution, volcanic source, etc.). Preliminary results indicate that this deposit may have been originated via sub-Plinian to Plinian eruption, which started with a steady column that moved to a waxing-waning column at the end, with a distribution axis of the tephra towards the northeast, and a potential volume of Pyroclasts up to 0.5 km^3. In this perspective, physical parameterization of volcanic activity can be pivotal to assess the hazard at Hasandağ, as well as the glass chemistry can contribute to understand the tephrostratigraphic framework, by compilation of a database for tephra correlations and synchronization of distal sedimentary records, which is also important to paleoenvironmental reconstructions and/or archeologic studies.

More than just a dating technique: determining the integrity of lake sediment records through tephrochronology

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The reliability, accuracy and validity of palaeoenvironmental reconstructions hinge upon the establishment of robust chronological control. Lake sedimentary sequences can be problematic to date for reasons including carbon reservoir effects, sediment disturbance and the in-wash of eroded organic material. Such records do, however, capture run-off from the surrounding area, making them ideal for a host of palaeoenvironmental methodologies, including geochemistry, sedaDNA and lipid biomarker analysis. Here we consider opportunities and challenges presented by sedimentary records from small lakes on islands sandwiched between Ireland and Scotland around the Sea of Moyle, and demonstrate important insights into the integrity of the sediment through the application of tephrochronology. The lakes offer possibilities to reconstruct a history of changing landscapes, environment and population history on the islands, providing an important basis for understanding the sustainability and resilience of complex socioecological systems over the Late Holocene. Initial ^{14}C rangefinder dates from the sequences revealed age-reversals and off-sets that posed barriers for establishing the age of the sediment. The application of tephrochronology presents a solution to the chronology, yet one that is at odds with a series of ^{210}Pb age estimates for the top of the core. The tephrostratigraphic record brings to light, however, systemic sediment disturbance through the sequences that highlight issues with establishing robust age control. We consider the implications of the tephra profile for understanding the palaeoenvironmental reconstructions from the lake sediment, and evaluate from the proxy records, including sedaDNA, whether the sediment mixing is clearly evident in the absence of the tephrostratigraphic data.

Characterization of three large holocene pyroclastic deposits from Mt Erciyes Stratovolcano (Central Anatolia, Turkey): Karagüllü, Perikartın and Dikkartın

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Mount Erciyes, the largest stratovolcano in Central Anatolian Volcanic Province (CAVP) with elevation of 3917 m, has erupted three voluminous pyroclastic deposits during the Holocene (Karagüllü, Perikartın and Dikkartın) by different flank vents associated with rhyolitic lava-domes. Tephra produced by these large explosive eruptions were injected into the troposphere and the related distal/ultra-distal ashes were found in Black Sea cores (Karagüllü ashes) and in Mediterranean Sea (Dikkartın ashes up to 600 km away from the source). In this work we aimed to petrologically characterize these Holocene deposits by chemical microanalyses of glasses and minerals, in order to better understand the plumbing system beneath Erciyes volcano, and the eruption processes governing the emplacement of the three deposits (Karagüllü, Perikartın and Dikkartın). According to minor differences in chemistry and mineralogy, zircon dating and sequence modeling support synchronicity at 8.9 ± 0.4 ka, as the result of one single volcanic event. Dikkartın products include plagioclase + amphibole + pyroxene + Fe-Ti oxides, whereas Karagüllü and Perikartın products include plagioclase + amphibole + pyroxene + biotite + Fe-Ti oxides. The amphibole geobarometry of Dikkartın, Perikartın, Karagüllü pyroclastic samples return shallow crystallization depths of 1.5-3.7 kbar, 1.5-3.2, and 1.7-4.3 kbar, respectively. Plagioclase phenocrysts from Dikkartın are slightly depleted in total alkali concentration (~1.6-7.6 wt%) relative to those from Karagüllü (~1.9-8.8 wt%). Glass geochemistry (major and trace element) shows that Karagüllü has slightly higher SiO_2 concentrations (~76-78 wt%) than Dikkartın (~75-76 wt%) and Perikartın (~75-77 wt%), whereas Dikkartın has a higher Zr content (~90-200 ppm) than Karagüllü and Perikartın (~30-140 ppm). Additionally, Dikkartın's glass exhibit slightly higher CaO (~1.3-2.5 wt%) and FeO (~1.2-2.3 wt%) concentrations than Karagüllü and Perikartın glasses (~0.8-1.5 wt% CaO and ~0.8-1.6 wt% FeO), although data align along the same compositional trend. Compositional mapping of zoned plagioclase phenocrysts shows that the CaO content increases from rim to core, while the opposite occurs for Na_2O. This normal zoning pattern is also associated with reverse zonation testifying to magma mixing phenomena.

Refining high spatial resolution trace element analysis of single-grain vitreous tephra shards by LA-ICP-MS

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Tephra layers, deposited in sedimentary archives can provide unique opportunities to synchronise palaeoclimatic and archaeological records over the Quaternary. Tephra correlation is based on the geochemical characteristics of tephra which are controlled by magmatic process of the source volcano. However, small non-visible ash layers (cryptotephra) shards usually have travelled long distances are usually found with particularly small size ranges, resulting in technical problems during geochemical analysis. Recent analytical developments of EPMA allows precise and accurate tephra major element compositions from very small tephra shards (Hayward, 2012)). The most common technique used to analyse trace elements for small tephra shards is downhole drilling with a very small laser spot, using LA-ICP-MS. However, this remains problematic as small shards are also very thin meaning the laser can ablate through the shard very rapidly limiting the duration of analysis, resulting in problems of downhole fractionation and low precision. This often minimises the application of LA-ICP-MS analyses in distal tephra studies, and restricts them to larger shards. Trace element compositions are important for tephra correlation as tephra from either the same source volcano or different sources can have the indistinguishable major element compositions if the magmatic processes are very similar.

Here we propose a rastering sampling strategy for small tephra trace element analysis on LA-ICP-MS. The rastering sampling strategy has been tested on MPI-DING glass standards and natural cryptotephra shards. The study demonstrates that the method of rastering the laser beam with a small spot size along the tephra surface generates a higher precision analysis profile, without the problem of downhole element fractionation when drilling with a smaller size laser beam. This is important as more ultra-distal cryptotephra being detected in multiple studies across the globe and many of these require trace elements to confirm correlations based in large part so far on major elements only.

New insights into Late-Pleistocene Campanian explosive volcanism using tephra deposits preserved in central Mediterranean marine cores

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Volcanoes experience physical and chemical changes spanning their entire life-cycle, giving rise to a range of behaviour, including changes in eruptive style, magnitude and frequency. This makes long-term reconstructions of past activity essential for accurate forecasting of future eruptive scenarios. Routinely, tephra deposits preserved close to the volcano are examined to reconstruct past behaviour, which in turn helps informs hazard assessments. Unfortunately, the burial and destruction of older eruption deposits by more recent activities regularly leads to gaps in the near-source eruption record, and while this is particularly problematic for low- to mid-intensity eruptions, it also extends to large magnitude events, all of which has negative implications for the accuracy of hazard assessments.

Fortunately, tephra deposits preserved in long, continuous and undisturbed sedimentary successions offer opportunities to fill the gaps in explosive eruption records. Here we exploit distal tephra deposits preserved in Mediterranean marine sediment cores from both the Tyrrhenian (DED87-08) and Adriatic (MD909-16) seas to help better constrain the timing and scale of past explosive volcanism at the active Campanian volcanoes (Campi Flegrei, Ischia Island and Vesuvius), Southern Italy. In this contribution we present major (EMP) and trace element (LA-ICP-MS) volcanic glass chemistry for newly identified visible and crypto- tephra deposits identified in the two examined marine sediment sequences. These geochemical fingerprints are used to identify the volcanic source of the tephra deposits, and to provide new insights into the frequency, scale, and ash dispersal of past eruptions at Campi Flegrei and Ischia.

A 30,000 yr high-precision eruption history in the north Izu Islands, off Tokyo, Japan

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Quaternary volcanoes in north Izu Islands, the north part of Izu-Bonin Arc, are composed of basalt to rhyolite volcanic islands. Comparing to other Quaternary volcanoes in the main Japanese Islands, their long-term explosive eruption histories established by tephrostratigraphy are limited. To constrain the tempo and frequency of explosive eruptions that occurred at both basalt and rhyolitic volcanoes in this area, we aimed to establish detailed tephrostratigraphical framework for terrestrial and marine tephras in north Izu Islands. Niijima and Kozushima Volcanoes located in the back arc side are originated from rhyolitic magma. Both volcanoes have erupted with less frequency than basaltic volcanoes such as Izu-Oshima and Miyake Volcanoes. Interestingly, Niijima and Kozushima Volcanoes erupted within a short interval of ca. 50 years in 9th century as last explosive eruptions. However, eruption histories for these volcanoes differ during last 30 kyrs. At Niijima Volcano, eruptions with the magnitude equivalent to the latest AD886 event (Nj-My) (>0.1 DRE km^3) have occurred every thousand years since the Miyatsukayama event (12.8-8.5 cal ka) (Kobayashi et al. 2020). On the other hand, at Kozushima Volcano preceding the latest eruption of AD 838 event (Kz-Tj; 0.54 DRE km^3), only Kz-CbA (30-22 ka) and Kz-CbB (ca. 30 ka) events have been recognized as explosive eruptions except unclear Kz-CbA' event (14-12.8 ka?) (Murata et al. 2021). Kz-CbB is stratigraphically immediately below representative widespread AT tephra (30 ka) originated from the Aira Caldera in South Kyushu, SW Japan.

By focusing on two stratigraphically short intervals of Nj-My/ Kz-Tj and AT/ Kz-CbB, it is possible to constrain the tempo and frequency of explosive eruptions on other volcanic islands such as Izu-Oshima and Miyake Volcanoes where eruptions have occurred more frequently.

Advances in New Zealand's Quaternary tephrochronostratigraphy using marine drill sites.

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North Island, New Zealand, hosts one of the most frequently active rhyolitic Quaternary systems in the world, the Taupõ Volcanic Zone (TVZ). The volcanic centres of the TVZ are aligned NE-SW within c. 300 km length and c. 60 km width on central North Island, parallel to the subduction front east of New Zealand. Nine calderas are recognised, and at least 34 caldera forming eruptions occurred during the Quaternary. At present, two volcanic centres, or calderas, are considered to be active.

The volcanic evolution of the TVZ <61 ka has been intensely studied based on onshore studies, but the older eruptive history is less known due to post-depositional erosion or burial of deposits by subsequent eruptions.

We present the Quaternary marine tephra record from eleven deep-sea drill sites covering the proximal and distal marine environment offshore of New Zealand, complementing earlier studies on distal marine sediments. Based on major and trace element compositions, the stratigraphic context and visual appearance of the marine tephras we identified 331 as primary deposits. Correlations between holes and sites across the study area reveal 165 individual Quaternary volcanic events, of which 35 were successfully linked to onshore correlatives.

The marine tephra record complements the Quaternary onshore record and allows to reconstruct the eruptive history of New Zealand's Quaternary TVZ.

There she blows! Unravelling the eruptive history of Aso volcano (Japan) using distal ash (tephra) deposits

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Aso (southwestern Japan) is one of the largest active volcanoes in the world, with a caldera that was formed and modified by a series of at least four catastrophic VEI 6 – 7 eruptions between ca. 270 to 87 ka. These caldera-forming events produced widespread ash deposits blanketing Japan and the surrounding seas, with the final Aso-4 event generating pyroclastic density currents that can be mapped over 160 km from source. Between these cycles, and to the current day, Aso is known to have remained very active, but the frequency and dispersal of these events are poorly constrained. This is unsurprising since the proximal exposures are limited and the numerous cataclysmic events have destroyed and buried older deposits. Here, we highlight the critical role that distal records play in evaluating the eruptive history and hazard potential of Aso caldera. We review the known distal occurrences of tephra deposits erupted from Aso, integrating new data from lake and marine sedimentary records across the East Asian/Pacific region. This detailed tephrostratigraphic framework highlights inconsistencies in tephra correlations and suggests large magnitude events were more frequent and widely-dispersed than previously anticipated. To further supplement this record, we use high-resolution sedimentary cores to identify non-visible ash (cryptotephra) deposits erupted from Aso, which provide new insight into the timing and dispersal of both pre- and post- caldera-forming events. The precisely dated Lake Suigetsu sediment core (central Japan) provides the most comprehensive distal eruption record for Aso, despite being over 530 km NE from the vent. The Suigetsu record is utilised to date and geochemically fingerprint (using major, minor and trace element glass compositions) thirteen ash fall events from Aso that reached the now densely populated regions of central Honshu. This work serves as a critical reminder that even in volcanic regions that are intensely studied, numerous large Quaternary explosive events remain poorly understood and many are undocumented. Unravelling the past eruptive history, repose intervals and magmatic characteristics is essential for calderas like Aso which pose a significant threat for populated regions.

Estimating method of the overflowing volume deposits at the Little Ice Age applied to the fossil branch of the Rhône, Bras de Fer (France)

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Crevasse splay is one of the landforms of stream hydrodynamic activity (Coleman 1969; Arnaud-Fassetta 2013). When preserved following avulsion, these geomorphological structures can serve as a proxy for the evaluation of a paleo-fluvial activity. The rise in the resolution and precision of spatial data makes it possible to detect and characterize these structures quantitatively and qualitatively.

This work illustrates estimating the volume of sedimentary deposits method applies to crevasses splays of the Bras de Fer palaeochannel, borrowed by the Rhône from 1587 to 1711 AD. Its years of operation, coinciding with the Little Ice Age (LIA), are distinguished by an exceptional development of the delta plain, as much as by this distributor's very brief activity of 124 years. The beginning of its active period is contemporary with a more attenuated period of LIA, while the end of its activity is marked by high hydraulicity and sedimentary inflow (Pichard 2014).

The IGN-LiDAR HD (2021) point cloud turns out to be the appropriate tool for high-resolution (50 cm) topographic analysis. T.J. Fleury's (2021) methodology applied to LiDAR data uses the attributes of each point such as intensity, number of returns as well as return number to produce a high-resolution DEM. Unlike similar products existing since 2015 as RGE Alti and Litto 3D (minimum resolution 1m2), the DEM LiDAR HD enables better identification of river palaeoforms preserved on the surface. It provides details on the micro-topography for imaging the slight altimetry variations of very flat environments. The cartographic spatial delineation of sedimentary deposition forms was made by the semi-automatic recognition classification from the DEM LiDAR HD, combined with ancient aerial images, Sentinel-1 radar images, and Infrared Color Orthoimages.

This data is coupled to the thicknesses of the crevasse splay, bank and floodplain deposits, which were identified in trenches and cores and then digitized in 3D as a Digital Outcrop Model. The 3D model of sedimentary structures was interpolated and extrapolated from these datasets.

Late Quaternary morphotectonic evolution of the Matese lake intramontane basin (Southern Apennines, Italy)

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The Matese lake Basin (hereinafter MLB) is a NW-SE oriented intramontane basin placed in the core of the carbonate Matese massif. The latter is placed in the axial and seismogenic belt of the Southern Apennines and includes the highest peak of the chain. Historical seismicity indicates that most of the strongest earthquakes (e.g., M > 6.5) that struck the Southern Apennines occurred in the surrounding of the Matese massif (i.e., to the north-east, east, and west of it). On the opposite, earthquakes in the core of the massif are rare and include the M 5.1, 29 December 2013 event. The epicentre of this event occurred to the south-east of the MLB, and shade light on the active tectonics in the central portion of the Matese massif. Noteworthy, the MLB exhibits diffuse fault-controlled landforms such as rectilinear scarps and triangular facets that point to a major role played by tectonics in shaping the basin. Fault strands downthrown the carbonate bedrock and led to the accumulation to a tens of metres thick sequence of lacustrine to alluvial deposits, whose precise thickness has not been defined up to now. In addition, such deposits mainly outcrop to the NE of the basin where large alluvial fan occur. The scarcity of outcropping Quaternary deposits makes the reconstruction of the active tectonics in the MLB hard to be solved. To unravel this issue, we combined detail scale geomorphological and stratigraphical data with geophysical measurements. The former datasets allow recognising the presence of tens to hundred metres long fault strands affecting the Quaternary filling of the basin, whereas geophysical investigation allow detailing the subsurface geometry of the downthrown carbonate bedrock. Furthermore, we collected samples of fluvio-lacustrine deposits with evidence of faults displacements, trying to perform absolute dating of such deposits with the aim of providing chronological constraints to fault activity. Overall, collected data allow discerning the recent morphotectonic evolution of the MLB and may provide useful data for the definition of the active tectonics in this poorly known portion of the Apennine chain.

Impact of the Mid-Pleistocene Transition on Meuse River Terraces in the Southern Netherlands

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River terrace deposits are excellent archives of paleoenvironmental conditions. They reflect the tectonic and climatic settings of their time of formation. For this reason, especially the Late-Pleistocene and Holocene terraces have been studied, because of their good state of preservation and their age control. Less is known about Early- and Middle-Pleistocene terraces. The Lower Meuse River, a major tributary of the Rhine River, located in the Southern Netherlands, exhibits a well-preserved terrace staircase which, for decades, has been intensely investigated. The spatial configuration of the terraces is well known, and indirect age constraints are available, which are mainly based on correlations made with the marine isotope record. This allows for delineating the boundaries of the Early, Middle and Late Pleistocene terraces.

The existing spatial and temporal constraints of these terraces make the Lower Meuse River terrace staircase a suitable object of study for understanding the effects of the Mid-Pleistocene Transition (MPT) in northwest European river systems. To achieve that, we aim to compare different terrace levels according to their ages, and main lithological and morphological parameters. More specifically, a comparison is drawn between Early-, Middle-, and Late Pleistocene terraces. Differences in sedimentary parameters and trends are expected as a result of the climatic deterioration and shift in the climate cycle caused at the MPT (1.2 – 0.8 Ma), as well as due to regional tectonics (uplift of the Ardennes massif). The comparative assessment helps to clarify how the Meuse River system responded to the MPT.

To achieve the proposed goals, this work presents an updated Meuse terrace map for the Southern Netherlands and adjacent areas in Belgium and Germany. A dense borehole database containing thousands of data points is used for calculating geometrical parameters of the terraces (thickness, top and base, gradient, incisional steps) and lithological composition.

Middle to Late Pleistocene sea-level markers along the coastal belt between Formia and Minturno, central Italy

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The southernmost coastal sector of Latium, central Italy, shows many markers of Quaternary sea-level changes. The about 30 km-long coastal belt includes the Monte di Scauri promontory, the Formia-Vindicio plain, the Monte Orlando promontory, and the northern Gaeta beach system separated by minor headlands. The whole south-facing arched coastal plain of Formia is relatively narrow being immediately bordered at its back by an impressive mountain ridge mainly made of Mesozoic carbonate rocks. Survey and measurements of sea-level markers have been carried out along the Gaeta Bay coastline and at Monte d'Argento in the Minturno plain. In the Vindicio area, a carbonate clastic deposit, never reported before in the maps of this sector, has been found at about 17 m a.s.l.: petrographic analysis of thin sections of these sediments suggests a deposition in an inter-tidal littoral environment as beachrock deposits. Different cementation facies indicate an early cementation in a littoral environment followed by supratidal main cementation. Altough this formation is similar to the marine bioclastic deposit often morphologically hung along the coasts of southern Italy ("panchina carbonatica" Auctt.), the 230Th/234U isotopic analysis has revealed a Late Pleistocene (pre-Tyrrhenian) age for it. Actually, this deposit may be attributed to the MIS 7.5, so testifying a recent and intense tectonic activity. A staircase of faults affected also the weathered horizon of the calcarenite developed at least during or after the warm climate conditions of MIS 5. Therefore, it can be assumed that the area of Vindicio underwent a significant tectonic stage in Quaternary times, with an average uplift rate of 0.2 mm/yr. At Monte di Scauri and Monte d'Argento sites fossil notches, lithodome holes, beach deposits, and other geomorphological markers are well-exposed along the rocky cliffs and locally displaced by faults. Also between Gaeta and the Circeo promontory, at an elevation ranging from 5 to 10 m a.s.l., other sedimentary and morphological markers are largely present. All these data allowed us to complete the framework of the morphotectonic evolution followed to the mid-upper Pleistocene uplift and indicate that the area was subject to a remarkable tectonic activity up to the MIS 5.1.

Climatic vs tectonic control in Late Quaternary evolution of the eastern Maiella foothills (Central Apennines, Italy)

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A case study from an area between the eastern slopes of the carbonate ridge of the Maiella Mountain and the valley floor of the Aventino River (eastern Abruzzi) points out to the importance of torrential and gravitational phenomena, i.e. mass movements, in landscape evolution.
The studied area is dominated by the northwest-trending Maiella anticline and its northern plunging end, by the hilly belt made up of thrusted terrigenous and clayey to marly alloctonous successions, and by monoclinal quite undeformed clayey-sandy and conglomerate deposits. These latter testify the persistence in the northern sector of a marine sedimentation throughout the Early Pleistocene - while the Maiella had already emerged - and quantify the magnitude of uplift since early Middle Pleistocene onwards. Its setting is a consequence of the Early Pliocene-Early Pleistocene compressive tectonics and of the Middle Pleistocene generalized and intense regional uplift.
After the final emersion from the sea and a first phase of continental sedimentation, when debris layers and large systems of alluvial fans have formed at the junction belt between the mountain area and the coast, the foothills east of the Maiella ridge experienced intense denudational and related sedimentary events, in a phase of intense and rapid uplift and relative base-level lowering partly coinciding with the cold climatic pulsations of the Late Pleistocene. Geodynamic and climatic factors have acted in synergy or have opposed each other favoring areal erosive phenomena, debris production, gravitational processes(i.e. mass transport), or deepening by linear incision of watercourses, selective erosion and relief inversion.
This work - developed in the context of the Italian National Geological Mapping Project (CARG) with the aim to propose an example to be exported to other similar contexts - attempts to outline the rapid succession of events that characterized the late Quaternary evolution of this sector of the Apennine chain. A multidisciplinary method that includes field surveys, facies analysis, dating, image interpretation, and topography analysis will be used to investigate predisposing and activation factors, climatic and tectonic control and geomorphological processes that have acted in the past and, to some extent, still act today influencing human activities.

Tropical barrier island systems on the Brazilian equatorial margin, NE Brazil

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The northern coast of the state of Rio Grande do Norte (RN) is classified as a semi-arid, semidiurnal mesotidal tropical coast and presents a very intense coastal dynamic. It is an erosion hotspot and in this context is outstanding the presence of barrier island-spits system, which isolate protected areas from the impact of the open sea. These bodies are inserted between two main fault systems, the Carnaubais and Afonso Bezerra systems, were oil industry and onshore wind power are installed. In this perspective, this study has as main objective the characterization of the tropical barrier island systems near the city of Macau/RN, under anthropic pressure, with applications to coastal erosion and environment, and petroleum reservoir analogs as well. The research has data on granulometry, gamma ray profile, calcium carbonate and organic matter content from 27 cores collected by the vibration method, which allows for continuous, undisturbed sampling of poorly consolidated materials. The results indicated the presence of different sedimentary deposits on their marine and terrestrial sides. The cores in the region towards the ocean present vertical sequences with a coarsening upward pattern, with fine sediment deposits, between the base and the intermediate portion, while the upper part of these cores present medium to fine sand. The set of cores facing the continent presents an inverse pattern, with fining upward, containing at its base sediment of coarse sand granulometry, grading towards the top to fine sand. A general fining upward pattern, presenting mud and very fine to fine sand, sometimes with medium sand, organic matter and fragments of bioclasts, were observed in the cores of the lagune area. These characteristics present in the studied cores allowed the identification of tidal flat, mangrove, beach/barrier island and tidal channel deposits, representative of high very energy tropical systems.

Submarine record from eruption-fed vertical density currents, Kermadec arc/Rangitāhua

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Marine tephra layers are assigned to explosive volcanism that distributes volcanic material through submarine density currents, pyroclastic flows that travel over the sea, and/or as fallout but transitions or combinations of these emplacement processes are still under debate.

In April 2022, the RV *Investigator* voyage IN2022-V02 surveyed submarine and island volcanoes and their adjacent basins in the intra-oceanic Kermadec arc/Rangitāhua. A 5.58 m long piston core was sampled at 2460 m below sea level in a topographically isolated basin 100 km northwest from Macauley volcano. At 3.70 m depth below seafloor, an unusual 34-cm-thick, normally graded and shard-rich interval grades from planar bedded medium sand to cross-bedded fine sand to massive silt. The unit has well-developed scour marks in pelagic mud at its base. The cross-bedded facies dominates the deposit in thickness and comprises multiple ripple sets made of beds with low and high angles. Both planar and cross beds are defined by alternating beds of clear and brown glass shards. Tube-shape shards are the dominant component, foraminifera are common, but pyroxene and feldspar crystal fragments are rare. The composition of the glass shards is dominated by a homogeneous rhyolitic composition, yet sub-dominant andesitic compositions are present. The homogeneous normal grading and glass shard composition strongly suggest the unit is eruption-fed and from a single event. The extensive planar to cross-bedded facies in this unit raise questions on transport and sedimentation processes. Reworking by ocean currents is unlikely in a deep-water basin where no obstacle is present. Vent-derived submarine density currents are an unlikely source because hundreds of m high topographic barriers occur between the closest (50-100 km) volcanoes and the cored site. Our current model includes settling from either an aerial volcanic plume or pyroclastic density currents travelling over water. The unit suggests particle transport by vertical density currents through the water column, followed by lateral deflection upon impact with seafloor into seafloor-hugging turbidity currents. Stratigraphic grading from planar to cross beds suggests transition from upper-flow to lower-flow regimes, demonstrating high velocity currents. Ongoing geochemical and sedimentological studies will further inform on provenance and emplacement processes.

A globally-synchronized absolute timescale for Marine Isotope Stage 19

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Radioisotopically dated sedimentary records provide unique information to reconstruct and understand past climate change. Such a chronological constraint is virtually lacking beyond the ranges of radiocarbon and U/Th dating (~55 ka and ~650 ka, respectively), leaving the chronology of most palaeoclimatic records reliant on far-afield and uncertain correlations. New, high-resolution ^{10}Be data, anchored to a detailed, sub-millennial-scale paleoclimate record for Marine Isotope Stage (MIS 19) constrained by high-precision ^{40}Ar/^{39}Ar dating from an Italian lacustrine succession, provide an age of 770.9±1.6 ka for the abrupt recovery of the geomagnetic field intensity that followed the Matuyama-Brunhes reversal. The temporal structure of this reversal proves to be complex and spatially heterogeneous, limiting its utility for high-resolution global synchronizations. By using our radioisotopically constrained record of the steadier ^{10}Be signal as global stratigraphic marker, we propose an inter-hemispheric synchronization of key palaeoclimatic time-series (i.e., the Antarctic EDC ice core and the Montalbano Jonico, southern Italy, and Chiba, Japan, marine successions), which allows reconciling the different chronologies of the millennial-scale events that punctuated MIS 19, the closest analogue to the present Holocene interglacial. Unlike astronomically-tuned records, our independent chronology allows us to assess the influence of astronomical forcing on glacial-interglacial and abrupt climate variability, avoiding circular reasoning.

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