ISAES 2019

XIII International Symposium on Antarctic Earth Sciences

22 July (Mon) – 26 July (Fri) , 2019
Songdo Convensia, Incheon, Republic of Korea

Abstract List – Oral

ISBN 978-0-948277-60-3

Oral Presentation

No.	Day	Time	Presenter	E-mail	Institution/Organization	Abstract no.	Session no.	Title
1	MON	11:00-11:30	John Smellie	jls55@le.ac.uk	University of Leicester, United Kingdom	A239	01	Victoria Land volcanism – a review
2	MON	11:30-11:45	Amin Beiranvand Pour	beiranvand.amin80@gmail.com	Korea Polar Research Institute, Korea	A205	01	Geological mapping in Morozumi Range and Helliwell Hills areas, Northern Victoria Land (NVL), Antarctica using remote sensing imagery
3	MON	11:45-12:00	Jusun Woo	jusunwoo@snu.ac.kr	Seoul National University, Korea	A345	01	Lithostratigraphy, biostratigraphy, and geochronology of the Bowers Supergroup in northern Victoria Land, Antarctica
4	MON	12:00-12:15	Taehwan Kim	slitmotw@snu.ac.kr	Seoul National University, Korea	A291	01	The Ediacaran continental rifting overpritned by the Cambrian Ross orogeny along the East Gondwana margin: new evidence from the Lanterman Range eclogite in northern Victoria Land
5	MON	12:15-12:30	Yoonsup Kim	yoonsup@cbnu.ac.kr	Chungbuk National University, Korea	A483	01	Preliminary reconnaissance of the Grenville basement and its Ross perturbation: contrasting zircon and monazite ages in a migmatitic gneiss from the Priestley Schist, northern Victoria Land, Antarctica
6	MON	12:30-12:45	Moonsup Cho	moonsup@snu.ac.kr	Chungbuk National University, Korea	A355	01	Early Paleozoic linkage between the Ross Orogen, Antarctica, and Korean Peninsula: A perspective from U-Pb detrital zircon ages of Cambrian–Ordovician sandstones in the Taebaeksan Basin, Korea
7	MON	15:00-15:30	David Elliot	elliot.1@osu.edu	The Ohio State University, USA	A334	01	Mesozoic volcanism in the Transantarctic Mountains
8	MON	15:30-15:45	Frank Lisker	flisker@uni-bremen.de	University of Bremen, Germany	A377	01	The youth of the Transantarctic Mountains: Late Mesozoic highland or sedimentary basin?
9	MON	15:45-16:00	Andreas Laufer	andreas.laeufer@bgr.de	Federal institute for geosciences and natural resources (BGR), Germany	A386	01	REGGAE: Tectonic history of the Rennick Graben (Antarctica) - International effort for Geology and Aeromagnetic Exploration
10	MON	16:00-16:15	Laura Crispini	laura.crispini@unige.it	University of Genova, Italy	A374	01	Hydrothermal fluids and fracturing along faults in the Rennick Graben (northern Victoria Land, Antarctica): a microstructural study
11	MON	16:15-16:30	Benjamin Bomfleur	bbomfleur@uni-muenster.de	Westphalian Wilhelms-University of Münster, Germany	A173	01	A palynostratigraphic age assessment of Permian and Triassic sedimentary deposits in the Helliwell Hills, central Rennick Glacier area
12	MON	16:30-16:45	Jan Unverfaerth	jan.un@uni-muenster.de	Westphalian Wilhelms-University of Münster, Germany	A177	01	GANOVEX XIII: New plant-fossil sites in the Permian to Jurassic Victoria Group (Beacon Supergroup) in Victoria Land, Antarctica
13	MON	16:45-17:00	Valentina Corti	valecorti7@gmail.com	University of Siena, Italy	A442	01	Reconstruction of paleoenvironmental change through paleo-dendrochronology analysis of a Triassic polar forest in Allan Hills (Antarctica)
14	WED	10:30-11:00	John Goodge	jgoodge@d.umn.edu	University of Minnesota Duluth, USA	A201	02	Origin and exhumation history of central East Antarctic igneous crust obtained from glacial erratics and by subglacial access drilling
15	THU	10:30-11:00	Graeme Eagles	graeme.eagles@awi.de	Alfred Wegener Institute, Germany	A394	02	Achievements and aspirations of AWI airborne geophysics in Antarctica
16	WED	11:00-11:15	Folker Pappa	folker.pappa@ifg.uni-kiel.de	Kiel University, Germany	A044	02	A 3D model of Antarctica's lithosphere from integrated and self-consistent modelling and its implications for GIA
17	THU	11:00-11:15	Hyungrae Kim	kimhr@kongju.ac.kr	Kongju National University, Korea	A347	02	Lithospheric magnetic anomaly modelling from Antarctic near-surface and satellite observations
18	THU	11:15-11:30	Simon Wilde	s.wilde@curtin.edu.au	Curtin University, Australia	A116	02	Crustal Evolution of the Archean Napier Complex
19	WED	11:15-11:30	Ian Fitzsimons	I.Fitzsimons@curtin.edu.au	Curtin University, Australia	A423	02	Spatial variations in effective elastic thickness reveal the subglacial lithospheric structure of Antarctica
20	THU	11:30-11:45	Evgenii Mikhalskii	emikhalsky@mail.ru	VNIIOkeangeologia, Russia	A049	02	The early Mesoproterozoic Filla Series in the Rauer Islands: a possible fragment of the long-lived Fraser– Fisher–Ongole oceanic realm
21	WED	11:30-11:45	Alan Aitken	alan.aitken@uwa.edu.au	The University of Western Australia, Australia	A125	02	New magnetic data processing methods give better data for better geology
22	THU	11:45-12:00	Joachim Jacobs	joachim.jacobs@uib.no	University of Bergen, Norway	A333	02	Proterozoic evolution of central Dronning Maud Land (East Antarctica) from Rodinia to Gondwana
23	WED	11:45-12:00	Andrew Lloyd	a.j.lloyd@go.wustl.edu	Washington University in St. Louis, USA	A415	02	Radially Anisotropic Seismic Structure of the Antarctic Upper Mantle Based on Full Waveform Adjoint Tomography
24	WED	12:00-12:15	Fausto Ferraccioli	ffe@bas.ac.uk	British Antarctic Survey, United Kingdom	A326	02	Tectonic and magmatic evolution of a distributed plate boundary in the South Pole Frontier
25	THU	12:00-12:15	Joachim Jacobs	joachim.jacobs@uib.no	University of Bergen, Norway	A332	02	Neoproterozoic geodynamic evolution of easternmost Kalahari: Constraints from new U-Pb-Hf-O zircon and Sm-Nd isotope data of basement rocks from the Schirmacher Oasis, East Antarctica
26	THU	12:15-12:30	Naresh Chandra Pant	pantnc@gmail.com	University of Delhi, India	A092	02	Corroboration of a branched Pan-African suture in Princess Elizabeth Land
27	WED	12:15-12:30	Kirsty Tinto	tinto@ldeo.columbia.edu	LDEO Columbia University, USA	A469	02	Locating the East-West Antarctica boundary beneath the Ross Ice Shelf
28	THU	15:00-15:15	Jörg Ebbing	joerg.ebbing@ifg.uni-kiel.de	Kiel University, Germany	A040	02	Combining satellite and aeromagnetic data in Antarctica – pitfalls and opportunities
29	WED	15:00-15:30	Ian Dalziel	ian@ig.utexas.edu	The University of Texas at Austin, USA	A286	02	South Georgia microcontinent: current tectonic setting from GPS and marine seismic data
30	THU	15:15-15:30	Zhengyang Zhou	zhou.z@wustl.edu	Washington University in St. Louis, USA	A325	02	Crustal and Uppermost Mantle Radial Anisotropy beneath Antarctica from Surface Wave Ambient Noise Tomography
31	WED	15:30-15:45	Roi Granot	rgranot@bgu.ac.il	Ben Gurion University, Israel	A303	02	Relative plate motion between East and West Antarctica since the Eocene: what we know and what we don't
32	THU	15:30-15:45	Jamin Greenbaum	jamin@utexas.edu	The University of Texas at Austin, USA	A437	02	Assembly and breakup of Indo-Antarctica revealed
33	THU	15:45-16:00	Alessandro Maritati	alessandro.maritati@utas.edu.au	University of Tasmania, Australia	A195	02	Permian-Triassic rifting shaped subglacial landscape of western Wilkes Land, East Antarctica
34	WED	15:45-16:00	Chiara Sauli	csauli@inogs.it	Istituto Nazionale di Oceanografia e Geofisica Sperimentale, Italy	A324	02	Geometry and Neogene evolution of Terror Rift, western Ross Sea, Antarctica
35	THU	16:00-16:15	Liu Chenguang	lcg@fio.org.cn	The First Institute of Oceanography, China	A168	02	Geophysical characteristics and tectonic evolutions of Jane basin, Weddell Sea
36	WED	16:00-16:15	Terry Wilson	wilson.43@osu.edu	The Ohio State University, USA	A464	02	Heterogeneous crustal motions across West Antarctica
37	THU	16:15-16:30	Daeyeong Kim	dkim@kopri.re.kr	Korea Polar Research Institute, Korea	A087	02	Microstructures of peridotites from the Mount Melbourne, Antarctica
38	WED	16:15-16:30	Yongcheol Park	ypark@kopri.re.kr	Korea Polar Research Institute, Korea	A473	02	UPPER MANTLE P-WAVE VELOCITY STRUCTURE BENEATH THE NORTHERN VICTORIA LAND: THE POSSIBLE HEAT SOUCE OF THE VOLCANOS
39	THU	16:30-16:45	Xiao-Gang Hu	hxg432@whigg.ac.cn	Chinese academy of sciences, China	A174	02	Observations of the azimuthal dependence of normal mode coupling at the South Pole and its nearby stations: Insights into azimuthal anisotropy beneath the Transantarctic Mountains
40	WED	16:30-16:45	Alex Burton-Johnson	alerto@bas.ac.uk	British Antarctic Survey, United Kingdom	A444	02	A tectonic control on the timing, chemistry and scale of voluminous pulsed intrusive magmatism: Evidence from the Lassiter Coast, Antarctic Peninsula
41	WED	16:45-17:00	Joaquin Bastias	j.bastias.silva@gmail.com	University of Geneva, Switzerland	A321	02	Late Triassic magmatism of Antarctic Peninsula and its implications for the Gondwanan margin of West Antarctica: a revised tectonic evolution
42	WED	17:00-17:15	Douglas Wiens	doug@wustl.edu	Washington University in St. Louis, USA	A319	02	Mantle viscosity structure and lithosphere thickness beneath Antarctica
43	TUE	10:30-11:00	Graham Hill	graham@antarcticascientific.com	Gateway Antarctica, New Zealand	A066	04	Imaging structural controls on the Erebus volcano magmatic system, Antarctica using the magnetotelluric method

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44	TUE	11:00-11:15	Choonki Lee	cklee92@kopri.re.kr	Korea Polar Research Institute, Korea	A330	04	Geoelectric structure of Mt. Melbourne, Antarctica from magnetotelluric data
45	TUE	11:15-11:30	Glenn Gaetani	ggaetani@whoi.edu	Woods Hole Oceanographic Institution, USA	A064	04	Magma Storage and Ascent Beneath the Erebus Volcanic Province, Antarctica: Insights from Olivine-Hosted Melt Inclusions
46	TUE	11:30-11:45	Kurt Panter	kpanter@bgsu.edu	Bowling Green State University, USA	A143	04	Origin and evolution of basalt from Earth's southernmost volcanoes
47	TUE	11:45-12:00	Jihyuk Kim	jihyuk008@snu.ac.kr	Seoul National University, Korea	A260	04	Evolution of Alkalic Magma Systems: Insight from Coeval Evolution of Sodic and Potassic Fractionation Lineages at The Pleiades Volcanic Complex
48	TUE	12:00-12:15	Anne Grunow	grunow.1@osu.edu	The Ohio State University, USA	A063	04	The Polar Rock Repository: a Scientific Resource for the Volcanology Community
49	TUE	15:00-15:30	John Smellie	jls55@le.ac.uk	University of Leicester, United Kingdom	A134	04	The role of volcanism in the making of Antarctica
50	TUE	15:30-15:45	David Elliot	elliot.1@osu.edu	The Ohio State University, USA	A085	04	Ferrar magma distribution: line source or restricted source and long distance transport?
51	TUE	15:45-16:00	Maria Luisa Tejada	marialuisa.tejada@gmail.com	Japan Agency for Marine-Earth Science and Technology, Japan	A099	04	Emplacement history of the volcanic sequence at Site U1513, Naturaliste Plateau and Mentelle Basin, IODP Expedition 369
52	TUE	16:00-16:15	Alessio Di Roberto	alessio.diroberto@ingv.it	Istituto Nazionale di Geofisica e Vulcanologia, Italy	A107	04	Marine tephra record of a Holocene caldera-forming eruption of Mt. Rittmann, Antarctica: volcanological reconstruction and perspectives for its use as tephrostratigraphic marker in the Ross Sea.
53	TUE	16:15-16:30	John Smellie	jls55@le.ac.uk	University of Leicester, United Kingdom	A135	04	Glaciovolcanic studies 300 km from South Pole: evidence for a highly dynamic Early Miocene East Antarctic Ice Sheet
54	TUE	16:30-16:45	Paola Del Carlo	paola.delcarlo@ingv.it	Istituto Nazionale di Geofisica e Vulcanologia, Italy	A192	04	Englacial tephra layers at Mt Melbourne (Antarctica): implications for recent volcanic activity
55	TUE	16:45-17:00	Adam Martin	a.martin@gns.cri.nz	GNS Science, New Zealand	A247	04	An uncommonly well-exposed Miocene caldera interior at Mason Spur, Antarctica: unusual trachytic spatter-rich lapilli tuff facies amid evidence for voluminous eruptions
56	TUE	17:00-17:15	Gibom Kim	gbkim42@gmail.com	Gyeongsang National University, Korea	A428	04	Shield Nunatak: An englacial tuya in the Melbourne volcanic field
57	TUE	17:15-17:30	Alex Burton-Johnson	alerto@bas.ac.uk	British Antarctic Survey, United Kingdom	A467	04	Death of an Arc: Exploring the 20 Ma cessation of the Antarctic Peninsula volcanic arc
58	TUE	10:30-11:00	Yoichi Motoyoshi	motoyosi@nipr.ac.jp	National Institute of Polar Research, Japan	A370	05	Letters from deep crust - What we received from Antarctica and Gondwana
59	TUE	11:00-11:30	Yue Zhao	yuezhao2307@163.com	Chinese Academy of Geological Sciences, China	A432	05	The Early History and Tectonic Framework of East Antarctica, Knowledge from the Subglacial Geology: A review
60	TUE	11:30-11:45	Evgenii Mikhalskii	emikhalsky@mail.ru	VNIIOkeangeologia, Russia	A046	05	The architecture of late Neoproterozoic – Cambrian Prydz orogen from new U–Pb zircon data, and some implications on its formation
61	TUE	11:45-12:00	Wei Wang	wangwei0521@gmail.com	Chinese Academy of Geological Sciences, China	A153	05	Ediacaran-Cambrian metamorphic evolution of the granulite terranes in the Larsemann Hills, East Antarctica: Response to the assembly of the East Gondwana.
62	TUE	12:00-12:15	Xiaochun Liu	liuxchqw@cags.ac.cn	Chinese Academy of Geological Sciences, China	A155	05	Early Neoproterozoic granulite facies metamorphism and possible Cambrian reworking at Mount Brown, East Antarctica
63	TUE	12:15-12:30	Jianmin Hu	jianminhu@vip.sina.com	Chinese Academy of Geological Sciences, China	A163	05	Sequences of the Metamorphic Complex, Tectonic Framework and Deformation Evolution in Larsemann Hills, Eastern Antarctica
64	TUE	15:00-15:30	Ian Fitzsimons	I.Fitzsimons@curtin.edu.au	Curtin University, Australia	A429	05	Ediacaran-Cambrian orogenesis in Gondwana – where were the Pan-African mountains?
65	TUE	15:30-15:45	Satish Kumar Madhusoodhan	satish@geo.sc.niigata-u.ac.jp	Niigata University, Japan	A299	05	Isotope geochemistry of metacarbonate rocks in continental collision zones as proxies for estimating the sedimentation age and understanding the tectonic setting of deposition
66	TUE	15:45-16:00	John Goodge	jgoodge@d.umn.edu	University of Minnesota Duluth, USA	A258	05	Ross Orogen: One-hundred forty-five million years of Gondwana-margin convergent plate evolution
67	TUE	16:00-16:15	Tomokazu Hokada	hokada@nipr.ac.jp	National Institute of Polar Research, Japan	A318	05	Dronning Maud Land - Enderby Land connection: views from metamorphic and geochronologic records in Rayner and Western Rayner Complexes, East Antarctica
68	TUE	16:15-16:30	Masaaki Owada	owada@yamaguchi-u.ac.jp	Yamaguchi University, Japan	A067	05	Proterozoic magma activities and formation of collision zone in the Sør Rondane Mountains, eastern Dronning Maud Land, East Antarctica
69	TUE	16:30-16:45	Geoffrey Grantham	ghgrantham@uj.ac.za	University of Johannesburg, South Africa	A072	05	THE CAMBRIAN UPLIFT HISTORY OF W. DRONNING MAUD LAND, ANTARCTICA : NEW 40AR/39AR AND SR AND ND DATA.
70	TUE	16:45-17:00	Conrad Groenewald	cgroenewald@geoscience.org.za	Council for Geoscience, South Africa	A447	05	New geochemical data from central Dronning Maud Land: Implications for Gondwana reconstruction.
71	TUE	17:00-17:15	Paula Castillo	paula.castillo@uni-muenster.de	Westphalian Wilhelms-University of Münster, Germany	A401	05	Context of the Ellsworth Mountains within East Antarctica and relationship with Laurentia
72	TUE	17:15-17:30	Mayuri Pandey	mayuri1414@gmail.com	Department of Geology, India	A282	05	Investigating the geological terrains hidden beneath the thick ice cover of Princess Elizabeth Land, Antarctica
73	WED	15:00-15:30	Yasmina M Martos	yasmina.martos@nasa.gov	NASA Goddard Space Flight Center/University of Maryland, USA	A216	06	Geothermal heat flow and its influence at the base of polar ice sheets
74	WED	15:30-15:45	Weisen Shen	weisen.shen@stonybrook.edu	Stony Brook University, USA	A357	06	A seismologically determined geothermal heat flux map of Antarctica
75	WED	15:45-16:00	Fausto Ferraccioli	ffe@bas.ac.uk	NERC/British Antarctic Survey, United Kingdom	A456	06	Antarctic Geothermal Heat Flux: Past, Present and Future perspectives
76	WED	16:00-16:15	Tobias Staal	tobias.staal@utas.edu.au	University of Tasmania, Australia	A082	06	Linking Antarctic geological observations and geophysical data in a probabilistic space.
77	WED	16:15-16:30	John Goodge	jgoodge@d.umn.edu	University of Minnesota Duluth, USA	A053	06	Crustal heat production and terrestrial heat flow in central East Antarctica, with implications for thermal input to the East Antarctic ice sheet
78	WED	16:30-16:45	Kenichi Matsuoka	matsuoka@npolar.no	Norwegian Polar Institute, Norway	A075	06	Bed diagnosis in the Dome Fuji region, East Antarctica, using airborne radar data and englacial attenuation estimates
79	WED	16:45-17:00	Enrica Quartini	equartini@utexas.edu	University of Texas Institute for Geophysics, USA	A420	06	Testing the hotspot hypothesis for Marie Byrd Land, West Antarctica using ice penetrating radar
80	WED	17:00-17:15	Erica Emry	erica.emry@nmt.edu	New Mexico Tech, USA	A413	06	Prominent mantle transition zone thinning beneath the Central Transantarctic Mountains
81	WED	17:15-17:30	Robert Mulvaney	rmu@bas.ac.uk	British Antarctic Survey, United Kingdom	A265	06	Estimating geothermal heat flux from ice sheet borehole temperature measurements
82	TUE	15:00-15:30	Howie D. Scher	hscher@geol.sc.edu	University of South Carolina, USA	A480	07	Commotion in the ocean revisited; putting tectonic gateways in their place
83	TUE	15:30-15:45	Andrew Lloyd	a.j.lloyd@go.wustl.edu	Washington University in St. Louis, USA	A414	07	Decoding Cenozoic Tectonics in Patagonia, the Scotia Sea, and the Antarctic Peninsula from New Seismic Tomography
84	TUE	15:45-16:00	Yue Zhao	Yuezhao2307@163.com	Chinese Academy of Geological Sciences, China	A156	07	The final subduction of the Phoenix plate beneath the Antarctic Peninsula: A prelude to the opening of the deep Drake Passage oceanic gateway
85	TUE	16:00-16:15	Joaquin Bastias	j.bastias.silva@gmail.com	University of Geneva, Switzerland	A341	07	Cenozoic magmatism along the Antarctic Peninsula: a new key to constrain Phoenix plate subduction and the development of the Scotia Arc
86	TUE	16:15-16:45	Carlota Escutia	cescutia@ugr.es	Spanish National Research Council (CSIC), Spain	A485	07	TBA
87	TUE	16:45-17:00	Jesus Galindo Zaldivar	jgalindo@ugr.es	Instituto Andaluz de Ciencias de la Tierra (IACT), Spain	A407	07	Early stages of oceanic spreading in the NE extremity of Antarctic Peninsula: relationships between Ona and Powell basins

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88	TUE	17:00-17:15	Adrian Lopez Quiros	alquiros@iact.ugr-csic.es	Spanish National Research Council (CSIC), Spain	A266	07	The South Orkney Microcontinent: an open door in the Weddell Sea mirroring the Cenozoic climate and tectonic impact of the opening of Drake Passage
89	TUE	17:15-17:30	Isabel Sauermilch	Isabel.Sauermilch@utas.edu.au	University of Tasmania, Australia	A202	07	Modelling with high-resolution bathymetry demonstrates tectonic gateway induced cooling of Antarctica
90	THU	15:00-15:30	Kirsty Tinto	tinto@ldeo.columbia.edu	LDEO Columbia University, USA	A463	08	Bathymetry and history of the Ross Ice Shelf
91	THU	15:30-16:00	Guy Paxman	guy.j.paxman@durham.ac.uk	Durham University, United Kingdom	A042	08	Reconstructions of Antarctic palaeotopography since the Eocene–Oligocene boundary and implications for ice sheet behaviour
92	THU	16:00-16:15	Alan Aitken	alan.aitken@uwa.edu.au	The University Of Western Australia, Australia	A038	08	A spatial-statistical assessment of the likely detritus supply from past ice-sheet changes in Wilkes Land, East Antarctica.
93	THU	16:15-16:30	Paul Winberry	paul.winberry@gmail.com	Central Washington University, USA	A458	08	Geologic Structure of the Crary Ice Rise
94	THU	16:30-16:45	Felix Norman Teferle	norman.teferle@uni.lu	University of Luxembourg, Luxembourg	A327	08	Present-Day Land and Sea Level Changes around South Georgia Island: Results from Precise Levelling, GNSS, Tide Gauge and Satellite Altimetry Measurements
95	THU	16:45-17:00	Katharina Hochmuth	kh355@leicester.ac.uk	University of Leicester, United Kingdom	A181	08	A suite of paleobathymetric grids of the Cenozoic Southern Ocean - a key to understanding the interlinked evolution of ocean circulation patterns and the Antarctic ice sheets
96	THU	17:00-17:15	Xiangbin Cui	cuixiangbin@pric.org.cn	Polar Research Institute, China	A101	08	Four seasons' airborne survey in the Princess Elizabeth Land, the largest data gap of Antarctica
97	THU	17:15-17:30	Peter Fretwell	ptf@bas.ac.uk	British Antarctic Survey, United Kingdom	A093	08	Bedmap3: the vision for a new ice thickness and subglacial topography dataset
98	TUE	10:30-10:45	Wai Ng	wng@ingemmet.gob.pe	Geological Mnnig and Metallurgical Institute, Peru	A421	09	Thermal regime of the active layer and permafrost below the Machu Picchu Peruvian station (Antarctic Peninsula): Preliminary results
99	TUE	10:45-11:00	Steph Mclennan	Stephanie.mclennan@ga.gov.au	Geoscience Australia, Australia	A089	09	Geomorphology and landscape vulnerability of the ice-free Vestfold Hills, East Antarctica
100	TUE	11:00-11:15	Mustafa Senkaya	msenkaya@ktu.edu.tr	Karadeniz Technical University, Turkey	A109	09	Permafrost of Barton Peninsula: Surveys by Seismic Tomography, Active Surface Waves and Microtremors
101	TUE	11:15-11:30	Kwansoo Kim	sincekks@kopri.re.kr	Korea Polar Research Institute, Korea	A350	09	A case study of vegetation variation in permafrost using Geophysical methods near the King-Sejong Station
102	TUE	11:30-11:45	Stefano Ponti	s.ponti@uninsubria.it	University of Insubria, Italy	A241	09	Dynamics of frost mounds and icing blisters in perennially frozen lake in continuous permafrost areas of continental Antarctica (Terra Nova Bay, 74° S)
103	TUE	11:45-12:00	Kate Swanger	Kate_Swanger@uml.edu	University of Massachusetts Lowell, USA	A142	09	Burial of cold-based glacier ice in the McMurdo Dry Valleys, Antarctica
104	TUE	12:00-12:15	Eliseo Flores	eliseof_789@hotmail.com	National Scientific and Technical Research Council, Argentina	A412	09	Genetic particularities of rock glaciers and protalus lobes in James Ross Island, Antarctic Peninsula
105	TUE	12:15-12:30	Ivan Alekseev	vanyukov07@rambler.ru	Saint Petersburg State University, Russia	A096	09	Characterization of ornithogenic factor in soil-forming processes in Maritime Antarctica
106	THU	15:00-15:15	Cliff Atkins	cliff.atkins@vuw.ac.nz	Victoria University of Wellington, New Zealand	A217	10	Too cold, too dry and no dust: McMurdo Dry Valleys, Antarctica
107	THU	15:15-15:45	Kate Swanger	Kate_Swanger@uml.edu	University of Massachusetts Lowell, USA	A139	10	Holocene stream degradation of pre-Holocene buried ice in the Dry Valleys: using optically stimulated luminescence dating of fluvial deposits
108	THU	15:45-16:00	David Elliot	elliot.1@osu.edu	The Ohio State University, USA	A233	10	Pre-middle Miocene landslide deposits in the central Transantarctic Mountains
109	THU	16:00-16:15	Mauro Guglielmin	mauro.guglielmin@uninsubria.it	Insubria University, Italy	A246	10	Spatio-temporal variability of Antarctic tafoni. Are thermal events directly responsible for cavernous weathering?
110	THU	16:15-16:30	Joseph Levy	jlevy@colgate.edu	Colgate University, USA	A059	10	Moisture after midnight: Inferred widespread soil salt deliquescence in McMurdo Dry Valleys soils during late-night relative humidity peaks
111	FRI	10:30-10:45	Alix Post	alix.post@ga.gov.au	Geoscience Australia, Australia	A050	11	Topographic and substrate control on active icesheet retreat during the Late Holocene, offshore Windmill Islands, Antarctica
112	FRI	10:45-11:00	Dominic Hodgson	daho@bas.ac.uk	British Antarctic Survey, United Kingdom	A232	11	Past and future dynamics of the Brunt Ice Shelf from seabed bathymetry, ice shelf geometry, and instrumental data
113	FRI	11:00-11:15	Jan Erik Arndt	Jan.Erik.Arndt@awi.de	Alfred Wegener Institute for Polar and Marine Research, Germany	A243	11	Past ice dynamics and unusual ramp bedforms offshore Brunt Ice Shelf, Weddell Sea
114	FRI	11:15-11:45	Robert Larter	rdla@bas.ac.uk	British Antarctic Survey, United Kingdom	A309	11	Insights into controls on Thwaites Glacier retreat from new high-resolution bathymetry and related data
115	MON	11:00-11:30	Florence Colleoni	fcolleoni@inogs.it	Istituto Nazionale di Oceanografia e Geofisica Sperimentale, Italy	A045	12	Ice-sheet ocean interactions at Hillary Canyon through time (Eastern Ross Sea, Antarctica)
116	MON	11:30-11:45	Lara Perez	larrez@bas.ac.uk	British Antarctic Survey, United Kingdom	A052	12	Miocene ice sheet oscillations in the Ross Sea embayment based on preliminary results of log-seismic correlations
117	MON	11:45-12:00	Sookwan Kim	skwan@kopri.re.kr	Korea Polar Research Institute, Korea	A249	12	Antarctic ice-sheet behavior in the Ross Sea outer continental margin in the late Miocene to early Pliocene from preliminary results of regional seismic stratigraphy and IODP Site U1522
118	MON	12:00-12:15	Rudy Conte	rconte@inogs.it	Ca Foscari University of Venice/Istituto Nazionale di Oceanografia e Geofisica Sperimentale, Italy	A231	12	The ODYSSEA Contourite Depositional System. Interpretation of seismic reflection profiles collected between the Iselin Bank and the Hillary Canyon (Ross Sea).
119	MON	12:15-12:30	Tim Van Peer	T.E.vanPeer@soton.ac.uk	University of Southampton, United Kingdom	A393	12	Pleistocene deep-water oxygenation during interglacial events in the Ross Sea, Antarctica: palaeomagnetic results from IODP Exp. 374
120	MON	12:30-13:00	Amelia Shevenell	ashevenell@usf.edu	University of South Florida College of Marine Science, USA	A351	12	Early to middle Miocene oceanographic conditions in the Ross Sea, Antarctica
121	MON	15:00-15:30	Richard Levy	r.levy@gns.cri.nz	GNS Science, New Zealand	A262	12	Climate thresholds, marine ice sheet expansion, and the role of sea ice across the Miocene Climate Transition.
122	MON	15:30-15:45	Sangbeom Ha	sb_ha@pusan.ac.kr	Pusan National University, Korea	A292	12	Glacio-marine sedimentation influenced by the Ross Ice Sheet in the continental slope and rise to the east of Pennell-Iselin Banks in the Ross Sea
123	MON	15:45-16:00	Philip J. Bart	pbart@lsu.edu	Louisiana State University, USA	A482	12	Estimates of West Antarctic Ice Sheet sediment and ice flux of the Bindschadler Ice Stream during the post-LGM
124	MON	16:00-16:15	Christina Hulbe	christina.hulbe@otago.ac.nz	University of Otago, New Zealand	A121	12	Beyond J9: New observations of the hidden ocean and sea floor sediments beneath the Ross Ice Shelf, West Antarctica
125	MON	16:15-16:30	Chiara Sauli	csauli@inogs.it	Istituto Nazionale di Oceanografia e Geofisica Sperimentale, Italy	A331	12	The dynamism of valley glaciers along the Borchgrevink coast (North Victoria Land, Antarctica) archived in the offshore Quaternary seabed landforms and within the Miocene buried glacio-fluvial delta
126	MON	16:30-16:45	Greer Gilmer	greer.gilmer@postgrad.otago.ac.nz	University of Otago, New Zealand	A426	12	Early Holocene sea-ice changes in the northwestern Ross Sea
127	MON	16:45-17:00	Hyunhee Rhee	hyun1741@korea.ac.kr	Korea University/Korea Institute of Science and Technology, Korea	A076	12	Cosmogenic evidence for MIS 4 timing of the local LGM in Terra Nova Bay, Antarctica
128	MON	17:00-17:15	Jamey Stutz	jamey.stutz@vuw.ac.nz	Antarctic Research Centre at Victoria University of Wellington, New Zealand	A218	12	Rapid and Dynamic Mid-Holocene Thinning of David Glacier, Antarctica
129	WED	16:00-16:15	Libao Gao	gaolb@fio.org.cn	The First Institute of Oceanography, China	A077	13	Recent change in SAMW and its impact on the Southern Ocean warming
130	WED	16:15-16:30	Grace Duke	grace.duke@postgrad.otago.ac.nz	University of Otago, New Zealand	A416	13	Pliocene-Pleistocene surface productivity along the Wilkes Land Margin, East Antarctica
131	WED	16:30-16:45	Manish Tiwari	manish@ncaor.gov.in	National Centre for Polar and Ocean Research, India	A342	13	Revisiting 'Iron Hypothesis': Productivity Variability at the Subtropical Front on Multi-Millennial Timescale

Oral Presentation

No.	Day	Time	Presenter	E-mail	Institution/Organization	Abstract no.	Session no.	Title
132	WED	16:45-17:00	Michael Bollen	bolmi518@student.otago.ac.nz	University of Otago, New Zealand	A211	13	Effects of environmental conditions on diatom communities and the δ13C of particulate organic matter in Terra Nova Bay.
133	THU	10:30-11:00	Taryn Noble	Taryn.Noble@utas.edu.au	University of Tasmania, Australia	A148	14	Early resumption of dense shelf water production during the past deglaciations
134	THU	11:00-11:15	Jaeil Lee	leeji@kopri.re.kr	Korea Polar Research Institute, Korea	A190	14	Late Quaternary carbonate dissolution cycle recorded in southern Drake Passage sediments
135	THU	11:15-11:30	German Leitchenkov	german_l@mail.ru	Research Institute for Geology and Mineral Resources of the World Ocean, Russia	A061	14	Post-breakup deposition off Prydz Bay (East Antarctica) with Focus on Cenozoic Environments
136	THU	11:30-11:45	Karsten Gohl	karsten.gohl@awi.de	Alfred Wegener Institute for Polar and Marine Research, Germany	A209	14	Continuous late Miocene to present records on West Antarctic Ice Sheet dynamics: Summary of IODP Expedition 379 to the Amundsen Sea
137	THU	11:45-12:00	Yasmina Martos	yasmina.martos@nasa.gov	NASA Goddard Space Flight Center/University of Maryland, USA	A193	14	Iceberg Alley and South Falkland Slope Ice and Ocean Dynamics
138	THU	12:00-12:30	Sunghan Kim	delongksh@kopri.re.kr	Korea Polar Research Institute, Korea	A213	14	Paleoceanographic changes in the Southern Ocean off Elephant Island since the Last Glacial Maximum
139	THU	15:00-15:30	Tim Naish	tim.naish@vuw.ac.nz	Victoria University of Wellington, New Zealand	A302	14	Antarctic-driven Pliocene global sea-level variability
140	THU	15:30-15:45	Sean Gulick	sean@ig.utexas.edu	The University of Texas at Austin, USA	A427	14	Proximal Aurora Basin records of glacial extent, subglacial hydrology, ice routing, and paleoenvironment: Keys to understanding climate sensitivity of the East Antarctic Ice Sheet
141	THU	15:45-16:00	Amelia Shevenell	ashevenell@usf.edu	University of South Florida College of Marine Science, USA	A404	14	East Antarctic Ice Sheet evolution and paleoclimate of the Aurora Subglacial Basin since the Late Cretaceous: Proposed geologic drilling on the Sabrina Coast continental shelf
142	THU	16:00-16:30	Juliane Müller	juliane.mueller@awi.de	Alfred Wegener Institute for Polar and Marine Research, Germany	A255	14	Ice-shelf and sea-ice dynamics: the biomarker perspective
143	THU	16:30-16:45	Carlota Escutia	cescutia@ugr.es	Spanish National Research Council (CSIC), Spain	A460	14	Insights into the Oligocene-Miocene transition at the Wilkes-Adelie Land margin
144	THU	16:45-17:00	Youngkyu Park	pyk125@yonsei.ac.kr	Yonsei University, Korea	A119	14	Identification of elemental composition of smectite tracing the sediment provenance in the glacial-interglacial period: Bellingshausen Sea
145	THU	17:00-17:15	Claus-Dieter Hillenbrand	hilc@bas.ac.uk	British Antarctic Survey, United Kingdom	A166	14	Multi-proxy investigations of a Late Quaternary sedimentary record from the continental slope in the Amundsen Sea, West Antarctica: Implications for oceanic forcing of ice-sheet changes
146	THU	17:15-17:30	Gerhard Kuhn	gerhard.kuhn@awi.de	Alfred Wegener Institute for Polar and Marine Research, Germany	A487	14	Pre-site surveys and plans for deep geological drilling below the Ekström Ice Shelf (Sub-EIS-Obs): Linking East Antarctic slope and shelf stratigraphy
147	FRI	10:30-10:45	Michael Wolovick	michael.wolovick@gmail.com	Beijing Normal University, China	A123	15	Potential for Extremely Old Ice at Dome A
148	FRI	10:45-11:00	Alexey Ekaykin	ekaykin@aari.ru	Arctic and Antarctic Research Institute, Russia	A313	15	On the possibility to restore the stable water isotope climatic signal from the highly disturbed section of old (0.4-1.2 Ma) Vostok ice
149	FRI	11:00-11:15	Sangyoung Han	greentail9@nate.com	Seoul National University, Korea	A366	15	Inhomogeneous greenhouse gas concentration distributions due to snow density layer in the firn at Styx, Antarctica
150	FRI	11:15-11:30	Joshua Kennedy	joshua.kennedy@sdstate.edu	South Dakota State University, USA	A106	15	Volcanic impact on chlorine chemistry: Evidence from perchlorate in Antarctic and Arctic ice cores
151	FRI	11:30-11:45	Laluraj C M	lalucm@gmail.com	National Centre for Polar and Ocean Research, India	A051	15	20th Century dust influx to east Antarctica: Causes and contribution to radiative forcing
152	FRI	11:45-12:00	Sergio Goncalves Junior	sjrgoncalves@gmail.com	Rio de Janeiro State University (UERJ), Brazil	A113	15	Impact of photochemical reactions on atmospheric particles in Antarctica
153	FRI	12:00-12:15	Wonyong Choi	wchoi@postech.edu	Pohang University of Science and Technology (POSTECH), Korea	A224	15	Accelerated chemical reactions in the frozen environments
154	FRI	12:15-12:30	Heon Kang	surfion@snu.ac.kr	Seoul National University, Korea	A278	15	Spontaneous reactions in cryogenic ice films. Enhanced dissociation of weak acids driven by mobile proton's entropy in ice
155	MON	15:00-15:30	Michael Gooseff	michael.gooseff@colorado.edu	University of Colorado Boulder, USA	A257	16	McMurdo Dry Valleys Stream Response to Annual Climate
156	MON	15:30-15:45	Sungwook Jeen	sjeen@jbnu.ac.kr	Chonbuk National University, Korea	A126	16	Surface Water-Groundwater Interactions in Two Small Lakes in Barton Peninsula, King George Island, Antarctica
157	MON	15:45-16:00	Peter Doran	pdoran@lsu.edu	Louisiana State University, USA	A411	16	Taylor Valley Perennially Ice-Covered Lakes, past, present and future elevations, ice cover and implications for Connectivity
158	MON	16:00-16:15	Matthew Siegfried	siegfried@mines.edu	Colorado School of Mines, USA	A285	16	Physical properties of a draining subglacial lake
159	MON	16:15-16:30	Xiaopeng Fan	heaxe@163.com	Jilin University, China	A055	16	New step forward in understanding Antarctic subglacial environment
160	MON	16:30-16:45	Felipe Napoleoni	felipe.a.napoleoni@durham.ac.uk	Durham University, United Kingdom	A128	16	The subglacial hydrology of the Ellsworth-Whitmore Mountains West Antarctica: newly identified subglacial lakes and the stability of water flow since the Mid-Pleistocene
161	MON	16:45-17:00	Christopher Gardner	gardner.177@osu.edu	The Ohio State University, USA	A220	16	Chemical Weathering and Meltwater Sources in Mercer Subglacial Lake, West Antarctica
162	MON	17:00-17:15	Brad Rosenheim	brosenheim@usf.edu	University of South Florida College of Marine Science, USA	A323	16	Challenges and successes coring sediments from Mercer Subglacial Lake
163	MON	17:15-17:30	Hyeontae Ju	hyeontae@kopri.re.kr	Korea Polar Research Institute, Korea	A328	16	Observation of the Subglacial Lake in the David Glacier area in Victoria Land
164	WED	10:30-10:45	Alexander Simms	asimms@geol.ucsb.edu	University of California Santa Barbara, USA	A188	17	Holocene Glacial Fluctuations across the Antarctic Peninsula
165	WED	10:45-11:00	Johan Etourneau	johan.etourneau@iact.ugr-csic.es	Instituto Andaluz de Ciencias de la Tierra (IACT), Spain	A314	17	Ocean temperature control on ice shelf and glacier extent around the Antarctic Peninsula throughout the Holocene
166	WED	11:00-11:15	Katelyn M. Johnson	katelyn.johnson@vuw.ac.nz	GNS Science, New Zealand	A290	17	Holocene drivers of biogenic bloom events linked to extratropical teleconnections, offshore Adélie Land, East Antarctica
167	WED	11:15-11:30	Theresa King	theresaking@mail.usf.edu	University of South Florida, USA	A461	17	Have we been right about the timing of the last deglacial in Antarctica?
168	WED	11:30-11:45	Duanne White	duanne.white@canberra.edu.au	University of Canberra, Australia	A358	17	Insights on the duration of late Pleistocene ice expansion from in-situ 14C dating of bedrock surfaces
169	WED	11:45-12:00	Zoe Roseby	Z.Roseby@noc.soton.ac.uk	University of Southampton, United Kingdom	A154	17	Deglacial history of the Anvers-Hugo Trough, western Antarctic Peninsula
170	WED	12:00-12:15	Francisco J. Jimenez Espejo	francisco.jimenez@iact.ugr-csic.es	Instituto Andaluz de Ciencias de la Tierra (IACT), Spain	A395	17	A HIGH RESOLUTION DEGLACIATION RECORD OF ADÉLIE LAND (EAST ANTARTIC MARGING; IODP SITE U1357A).
171	WED	15:00-15:15	Bridget Lee	blee045@ucr.edu	University of California Riverside, USA	A036	17	Coupled Iron and Carbon Cycling in the Southern Ocean and Impacts on Global Climate
172	WED	15:15-15:30	Jinwook Kim	jinwook@yonsei.ac.kr	Yonsei University, Korea	A120	17	Biogeochemical modification of clay minerals in Antarctic region: Implications
173	WED	15:30-15:45	Claudio Mazzoli	claudio.mazzoli@unipd.it	University of Padova, Italy	A140	17	Towards the complete mineralogical screening of Antarctic biogenic carbonates
174	WED	15:45-16:00	Ryan Venturelli	raventurelli@mail.usf.edu	University of South Florida, USA	A284	17	Subglacial Carbon Pathways Associated with Whillans and Mercer ice streams: A SALSA and WISSARD Sedimentary Perspective
175	TUE	15:00-15:15	Seunghee Kim	seunghee@kopri.re.kr	Korea Polar Research Institute, Korea	A310	18	Estimation of ice shelf thinning derived from surface depression of an ice rumple

Oral Presentation

No.	Day	Time	Presenter	E-mail	Institution/Organization	Abstract no.	Session no.	Title
176	TUE	15:15-15:30	Jamin Greenbaum	jamin@utexas.edu	University of Texas Institute for Geophysics, USA	A438	18	Ocean-driven thinning of Totten and Shackleton Ice Shelves, the two primary outlets of the Aurora Subglacial Basin in East Antarctica
177	TUE	15:30-15:45	Chunxia Zhou	zhoucx@whu.edu.cn	Wuhan University, China	A454	18	Mass Balance Assessment of the Lambert Glacier-Amery Ice Shelf System , East Antarctica
178	TUE	15:45-16:00	Iman Heidarpour	i.heidarppour@kopri.re.kr	Korea Polar Research Institute, Korea	A207	18	KOMPSAT5 Satellite Sea-Ice Image High-Frequency Multiplicative Noise Effects Analysis Based on Joint Complex Time-Frequency Domain Method
179	TUE	16:00-16:15	Hyangsun Han	hyangsun@kopri.re.kr	Korea Polar Research Institute, Korea	A274	18	Monitoring iceberg A68 calved from the Larsen C Ice Shelf using satellite remote sensing
180	TUE	16:15-16:30	Suvrat Kaushik	suvrat.k007@gmail.com	Indian Institute of Remote Sensing, India	A191	18	Sea ice extent and variability monitoring and wind speed retrieval along polar Marginal Ice Zones using SCATSAT-1 scatterometer and SAR data
181	TUE	16:30-16:45	Craig Stevens	craig.stevens@niwa.co.nz	The University of Auckland, New Zealand	A176	18	Ocean Processes South of the Drygalski Ice Tongue, Western Ross Sea
182	TUE	16:45-17:00	Yuwei Xia	marcella_yw@foxmail.com	Beijing Normal University, China	A115	18	Ocean Heat Transport Variability off Wilkes Land, East Antarctica
183	MON	11:00-11:30	Sheeba Chenoli	sheeba@um.edu.my	University Malaya, Malaysia	A296	19	The Linkage between the Antarctic Sea Ice Extent in Indian Ocean sector and the Indian Summer Monsoon Rainfall
184	MON	11:30-11:45	Sangjong Park	sangjong@kopri.re.kr	Korea Polar Research Institute, Korea	A281	19	30-YEAR CLIMATOLOGY OBSERVED AT KING SEJONG STATION, ANTARCTICA
185	MON	11:45-12:00	John Moore	john.moore.bnu@gmail.com	Beijing Normal University, China	A229	19	What can stratospheric aerosol injection geoengineering do for Antarctic ice mass loss - lessons from Greenland
186	MON	12:00-12:15	Emilia Kyung Jin	jin@kopri.re.kr	Korea Polar Research Institute, Korea	A373	19	The future projection of ice sheet melting and sea level rise under the RCP scenarios
187	MON	12:15-12:30	Jaho Koo	zach45@yonsei.ac.kr	Yonsei University, Korea	A124	19	Relationship between total ozone and regional meteorology around the Weddell Sea
188	MON	12:30-12:45	Wonseok Seo	wonseok0623@kopri.re.kr	Korea Polar Research Institute, Korea	A340	19	Characteristics of Atmospheric Boundary Layer at the Jang Bogo Station, Terra Nova Bay, East Antarctica in Summer
189	MON	12:45-13:00	Kyonghwan Seo	khseo@pusan.ac.kr	Pusan National University, Korea	A364	19	Impact of the Madden-Julian oscillation on Antarctic sea ice
190	MON	15:00-15:30	Sangyoon Jun	syjun@kopri.re.kr	Korea Polar Research Institute, Korea	A279	19	Two leading modes of Antarctic surface temperature and their contributions to Antarctic surface climate change
191	MON	15:30-16:00	Suchithra Sundaram	suchithra.sundaram@nyu.edu	New York University, UAE	A035	19	Does the combined effect of the Indian summer monsoon and Indian Ocean Dipole modulate the September Antarctic sea ice?
192	MON	16:00-16:15	Taejin Choi	ctjin@kopri.re.kr	Korea Polar Research Institute, Korea	A226	19	Characteristics of Surface Meteorology at Lindsey Islands, Amundsen Sea, West Antarctica
193	MON	16:15-16:30	Ziyin Zhang	zzy_ahgeo@163.com	Institute of Urban Meteorology, China Meteorological Administration, China	A026	19	Possible influence of the Antarctic Oscillation on haze pollution in North China
194	MON	16:30-16:45	Dhahyun Ahn	devorahn711@gmail.com	Yonsei University, Korea	A250	19	Potential effect of air pollution from the subtropical Southern hemisphere to Antarctica: spatiotemporal patterns of AOD, CO, NO2, and HCHO revealed by satellite observations
195	MON	16:45-17:00	Vladyslav Tymofeyev	tvvladys@gmail.com	Ukrainian Hydrometeorological Institute, Ukraine	A105	19	Climate variability in the West Antarctic sector and potential of seasonal predictability of the tropica Pacific and Atlantic zone
196	MON	17:00-17:15	Seongjoong Kim	seongjkim@kopri.re.kr	Korea Polar Research Institute, Korea	A039	19	Recent Antarctic Peninsula cooling derived by southern stratospheric polar vortex weakening
197	WED	10:30-11:00	Hector Mansilla Vera	hmansilla@inach.cl	Chilean Antarctic Institute, INACH, Chile	A418	20	The paleontological heritage of Fossil Hill Formation on the King George Island. An Early Eocene Lagerstätten from Antarctic?.
198	WED	11:00-11:15	Bo Deng	bo_deng@163.com	ShangHai Ocean University, China	A381	20	Variation in fatty acid composition and diet of Antarctic krill (Euphausia superba) in the Bransfield Strait during autumn 2017 and 2018
199	WED	11:15-11:30	Mi Duan	duanmi_1995@163.com	Shanghai Ocean University, , China	A380	20	Otolith edge chemistry reveals the role of water mass in structuring Electrona antarctica population in the Antarctic Circumpolar Current system
200	WED	11:30-11:45	Latife Cakir Bayram	lcakir@erciyes.edu.tr	Erciyes University, Turkey	A475	20	The Cytological, Microbiological and Ophthalmic Evaluation of Ocular Surface Samples Taken from Penguin Species of the Antarctic Peninsula : Preliminary evaluation of the results belong to ten eye swabs
201	WED	11:45-12:00	Michael Wethington	wethi002@umn.edu	Polar Geospatial Center, USA	A462	20	Using Very- and Ultra-High resolution Digital Elevation Models in Antarctic Biological Research
202	FRI	10:30-10:45	Catherine Huerta	catherinne.huerta@gmail.com	Universidad Católica de Temuco, Chile	A114	21	Preliminary results of a geomicrobiological study in the Madre de Dios archipelago
203	FRI	10:45-11:00	Oksun Kim	oskim@kopri.re.kr	Korea Polar Research Institute, Korea	A367	21	Distinctive microbial assemblages and their ecological function in permanently ice-covered lakes of the Dry Valleys, Antarctica
204	FRI	11:00-11:15	Yuzhong Zhang	zhangyz@sdu.edu.cn	Shandong University, China	A379	21	Mechanistic insight into 3-methylmercaptopropionate metabolism and kinetical regulation of demethylation pathway in marine dimethylsulfoniopropionate-catabolizing bacteria
205	FRI	11:15-11:45	José Perez Donoso	jose.perez@unab.cl	Andrés Bello National University National University, Chile	A405	21	Geomicrobiology studies at Union Glacier in the Ellsworth mountains: microbial survival in one of the most extreme environments in Antarctica
206	FRI	11:45-12:00	Vicente Cabrera Opazo	cavi.contacto@gmail.com	Andrés Bello National University National University, Chile	A453	21	Bioprecipitation of calcium carbonate induced by bacteria isolated from regolith of Ellsworth Mountains
207	FRI	12:00-12:30	Jill Mikucki	jmikucki@utk.edu	University of Tennessee, USA	A472	21	Geomicrobiological transformations in Antarctic subglacial environments
208	WED	15:00-15:30	Mathieu Morlighem	mmorligh@uci.edu	University of California Irvine, USA	A215	22	BedMachine Antarctica v1: a new subglacial bed topography and ocean bathymetry dataset of Antarctica
209	WED	15:30-16:00	Simon Cox	s.cox@gns.cri.nz	GNS Science, New Zealand	A252	22	Release of the continent-wide dataset GeoMAP v.201907
210	WED	16:00-16:30	Chang Qing Ke	kecq@nju.edu.cn	Nanjing University, China	A339	22	Mass balance of Antarctic ice sheet based on CryoSat-2 from 2011-2018
211	WED	16:30-16:45	Esha Shah	eshu7456@gmail.com	Gujarat University, India	A293	22	Change Detection over the major ice shelves of Antarctica using RADARSAT and Sentinel Data
212	WED	16:45-17:00	Brandi Downs	downs.152@osu.edu	The Ohio State University, USA	A137	22	Observing the Cryosphere with Next Generation GNSS-Reflectometry
213	WED	17:00-17:15	Amin Beiranvand Pour	amin.beiranvand@kopri.re.kr	Korea Polar Research Institute, Korea	A023	22	Mapping poorly exposed lithologies using Landsat-8 and ASTER satellite data in Antarctic Peninsula
214	WED	17:15-17:30	Changuk Hyun	chyun@kopri.re.kr	Korea Polar Research Institute, Korea	A360	22	High-resolution remote sensing techniques for monitoring penguin colonies in the Ross Sea, Antarctica
215	THU	10:30-11:00	Stephen Yan	jbyan@ua.edu	University of Alabama, USA	A305	23	Ultra-Wideband Multiple Input and Multiple Output Radar for Airborne Ice Sounding and Imaging
216	THU	11:00-11:15	Changhyun Chung	ch.chung@kopri.re.kr	Korea Polar Research Institute, Korea	A261	23	Development of OPV (Optional Piloted Vehicle) for Polar Research
217	THU	11:15-11:30	Stephen Yan	jbyan@ua.edu	University of Alabama, USA	A306	23	Ultra-wideband Microwave Radars for Airborne Mapping of Near-Surface Internal Layers in Polar Firn and Ice
218	THU	11:30-11:45	Hyomin Kim	hmkim@njit.edu	New Jersey Institute of Technology, USA	A169	23	Autonomous Instrument Network for Coordinated Observations at Remote Antarctic Locations
219	THU	11:45-12:00	Rusheng Wang	wangrs@jlu.edu.cn	Jilin University, China	A147	23	A New Smart System of Rapid Continuous Coring Drilling with Air Reverse Circulation in Antarctica

Oral Presentation

No.	Day	Time	Presenter	E-mail	Institution/Organization	Abstract no.	Session no.	Title
220	THU	12:00-12:15	Yafei Wang	wangyf1997@foxmail.com	Jilin university, China	A132	23	Hydraulic fracturing in fissured ice borehole wall: theory and tests
221	THU	12:15-12:30	Koichiro Doi	doi@nipr.ac.jp	National Institute of Polar Research, Japan	A354	23	Absolute Gravity Measurements in 2017/2018 and 2018/2019 Season in Dronning Maud Land and Enderby Land, East Antarctica
222	THU	16:30-17:00	Jeronimo Lopez Martinez	jeronimo.lopez@uam.es	Autonomous University of Madrid, Spain	A478	24	Recent advances on Antarctic geoconservation
223	THU	17:00-17:15	Falk Huettmann	fhuettmann@alaska.edu	University of Alaska Fairbanks, USA	A197	24	Use of 'boosting', 'bagging', ensembles (Machine Learning) and telecoupling for data mining and predictions of open access biodiversity: an example on charismatic penguins
224	THU	17:15-17:30	Nadia Tamara Manograsso Czalbowski	tamamc2903@gmail.com	Instituto Antartico Argentino, Argentina	A270	24	Involving Antarctic communities in the management of geoheritage: a case study in
225	FRI	10:30-10:45	Maribel Guzman	mguzman@pucp.edu.pe	Pontifical Catholic University of Peru, Peru	A141	26	Pollution assessment in the Bransfield Strait in the Antarctic
226	FRI	10:45-11:00	Luis Cerpa	lcerpa@gmail.com	Instituto Geológico Minero y Metalúrgico, Peru	A419	26	Presence of heavy metals in McKellar inlet, Admiralty Bay, King George Island, Antarctica
227	FRI	11:00-11:15	Masaki Kanao	kanao@nipr.ac.jp	National Institute of Polar Research, Japan	A025	26	Characteristic multi-sphere interaction in the coastal and marine environment inferred from infrasound observation at Terra Nova Bay, Antarctica
228	FRI	11:15-11:30	Songtao Ai	ast@whu.edu.cn	Wuhan University, China	A189	26	Iceberg-induced tsunami events observed by tide gauge at the Zhongshan Station, Antarctica
229	FRI	11:30-11:45	Minoru Ikehara	ikehara@kochi-u.ac.jp	Kochi University, Japan	A466	26	Episodic enhancement of sea ice survivability in the glacial Southern Ocean driven by Antarctic warming
230	FRI	11:45-12:00	Michael Wolovick	michael.wolovick@gmail.com	Beijing Normal University, China	A122	26	Stopping the Flood: Continued Progress in Targeted Glacial Geoengineering
231	FRI	12:00-12:15	Marc Oliva	oliva_marc@yahoo.com	Universitat de Barcelona, Spain	A343	26	THE DEGLACIATION PROCESS OF ICE-FREE ENVIRONMENTS IN THE SOUTH SHETLAND ISLANDS
232	FRI	12:15-12:30	Junhwa Chi	jhchi@kopri.re.kr	Korea Polar Research Institute, Korea	A329	26	Spectral characteristics of the Antarctic vegetation: A case study of the Barton Peninsula
233	FRI	12:30-12:45	Latife Cakir Bayram	lcakir@erciyes.edu.tr	Erciyes University, Turkey	A481	26	The Cytological, Microbiological and Ophthalmic Evaluation of Ocular Surface Samples Taken from Penguin Species of the Antarctic Peninsula : Preliminary evaluation of the results belong to ten eye swabs

Session01: Geological History of Victoria Land: Reviews and New Findings

A palynostratigraphic age assessment of Permian and Triassic sedimentary deposits in the Helliwell Hills, central Rennick Glacier area

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We present preliminary results of palynological analyses of Beacon Supergroup deposits in the far north of Victoria Land, a rarely visited and poorly explored region of the Transantarctic Mountains. Joint field work in the central Rennick Glacier area during the 2015–16 season resulted in the discovery of previously unknown sedimentary units of the Beacon Supergroup in that area. Overlying the Permian Takrouna Formation, which contains evidence of syn-sedimentary tectonics, is an over 75-m-thick unit (new unit 1) of mainly reddish-weathering quartzose sandstone, which is in turn overlain by a 235-m-thick unit (new unit 2) dominated by fossiliferous overbank mudstone with intercalations of greenish-weathering, mid-grained volcaniclastic sandstone. Palynomorph assemblages from the top of the Takrouna Formation are dominated by taeniate bisaccate pollen, and contain Praecolpatites sinuosus, Granulatisporites trisinus, and Dulhuntyispora species, allowing correlation with the eastern Australian late Permian unit APP5 of Price 1997. Two samples from the overlying new unit 1 have yielded moderately well-preserved assemblages with abundant fragments of non-taeniate bisaccate grains (Scheuringipollenites sp.), leiosphaerid acritarchs, cavate trilete spores (e.g., Densoisporites spp.), and rare specimens of Playfordiaspora crenulata, indicating correlation with zone APP6 (?latest Permian-earliest Triassic). All samples from the upper new unit 2 are dominated by non-taeniate bisaccate grains. The lowermost sample further contains common cavate trilete spores, various species of Aratrisporites, and Staurosaccites quadrifidus, indicative of the Middle Triassic zone APT3; two samples from the central and the top parts of the unit additionally contain common bryophyte spores, including Rogalskaisporites spp. and Annulispora spp., indicative of the early to mid-Late Triassic zone APT4. Altogether, the sedimentary succession in the Helliwell Hills region thus promises to hold a continuous section across the Permian-Triassic boundary, the most severe biotic crisis of the Phanerozoic. Recent return visits to the potential boundary section in the course of the 13th German Antarctic North Victoria Land Expedition (GANOVEX XIII) in the 2018-19 season enabled more comprehensive and higher-resolution sampling, which will allow more detailed palynostratigraphic analyses.

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GANOVEX XIII: New plant-fossil sites in the Permian to Jurassic Victoria Group (Beacon Supergroup) in Victoria Land, Antarctica

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The Devonian to Jurassic Beacon Supergroup of the Transantarctic Mountains has yielded exceptionally well-preserved plant fossils. Extensive fossil collections especially from South Victoria Land have contributed greatly to the stratigraphy and palaeoenvironmental interpretation of these deposits. The geology and palaeontology of the Beacon Supergroup in North Victoria Land, however, is still poorly known; many outcrop areas have only rarely been visited, and stratigraphic relationships are in many cases unclear. During the 13th German Antarctic North Victoria Land Expedition (GANOVEX XIII, 2018/2019), we visited old and new locations for collection of late Palaeozoic and Mesozoic plant fossils in three major study areas: (1) In North Victoria Land within helicopter range of the Gondwana Station, namely the Eisenhower, Deep Freeze and Mesa ranges; (2) in the Helliwell Hills, central Rennick Glacier; and (3) in the southern Prince Albert Mountains in South Victoria Land, via helicopter reconnaissance and a satellite camp. During 26 days of field work, we visited 39 different locations and collected 450 kg of micro- and macrofossils. High-resolution palynological samples were taken across a potential Permian-Triassic boundary section in the Helliwell Hills (central Rennick Glacier) and at Triassic-Jurassic transition outcrops in the Eisenhower Range. At Helliwell Hills, syn-sedimentary deformation in the Takrouna Formation of the Beacon Supergroup suggest active tectonism in the late Permian in North Victoria Land. Several outcrops of uncertain stratigraphic assignment in the southern Prince Albert Mountains were sampled for a first palynological age assessment. In addition, we found several new plant-fossil deposits with petrified wood, plant foliage, and silicified peat. This presentation gives an overview about newly collected plant fossils from Victoria Land, including Permian and Triassic seed ferns (Glossopteridales, Umkomasiales), Triassic horsetails (Equisetales), and Triassic and Jurassic ferns and cycadophytes. We anticipate that detailed analyses of these newly collected plant macro- and microfossil assemblages will enable better correlation of the regional stratigraphic schemes of northern and southern Victoria Land.

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Geological mapping in Morozumi Range and Helliwell Hills areas, Northern Victoria Land (NVL), Antarctica using remote sensing imagery

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Many regions remain poorly studied in terms of geological mapping in inaccessible regions especially in the Arctic and Antarctica due to harsh conditions and logistical difficulties. Application of specialized image processing techniques is capable of revealing the hidden linearly mixed spectral sources in multispectral and hyperspectral satellite images. In this study, the application of Independent component analysis (ICA) and Constrained Energy Minimization (CEM) algorithms was evaluated for Landsat-8 and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) remote sensing data for geological mapping in Morozumi Range and Helliwell Hills areas, Northern Victoria Land (NVL), Antarctica. ICA algorithm was able to detect hidden linearly mixed spectral sources and low probability target materials in Landsat-8 and ASTER datasets. Fraction images of endmember target minerals such as hematite, goethite, jarosite, alunite, kaolinite, muscovite, epidote, chlorite, calcite, quartz, opal and chalcedony were produced using CEM algorithm for two spatial subsets of ASTER scene covering the Morozumi Range and Helliwell Hills areas. CEM classification image maps indicated that chlorite/hematite, goethite/jarosite/calcite and kaolinite/muscovite are governed in the Morozumi Range and goethite, chlorite, hematite and epidote are most dominated mineral assemblages in the Helliwell Hills area. GPS survey and XRD analysis verified the alteration mineral assemblages detected by ICA and CEM image processing algorithms. The results of this investigation demonstrate the capability of the two algorithms in distinguishing pixel and subpixel targets in the multispectral satellite data. The application of the methods for identifying poorly exposed geologic materials and subpixel exposures of alteration minerals has invaluable implications for geological mapping and mineral exploration in inaccessible regions.

Session01: Geological History of Victoria Land: Reviews and New Findings

Victoria Land volcanism – a review

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Neogene volcanism in Victoria Land spans the period between c. 19 Ma and present, and it includes active volcanoes at Mt Erebus, Mt Melbourne and possibly at Mt Rittmann. However, it may have commenced as early as Eocene time (c. 50 Ma), as represented by the Meander Intrusive Group, which would also have constructed large volcanic edifices. The volcanism has been the subject of much petrological research over many decades and a consensus is emerging that it owes its origin to two principal distinct mechanisms: (1) mantle plumes, and (2) edge flow associated with thermal anomalies linked in some way to plate separation. By contrast, the volcanology has been relatively cursorily studied and poorly understood. That is now changing since its value for understanding past environmental change has become recognised. The volcanism is the sole onshore record of Mio-Pliocene terrestrial conditions in the region. It is characterised by large long-lived (multi-million year) shield- and stratovolcanoes and by numerous small short-lived pyroclastic cones. The large centres have been a major target for recent investigations, with a focus principally on uncovering and documenting evidence of past ice (i.e. glaciovolcanism). As a result, we now know that ice during glacials was typically thin and draped the landscape. Moreover, the basal thermal regime was apparently polythermal and did not evolve in a single irreversible step-change as was predicted by the prevailing paradigm. A change in the paradigm is therefore required. Currently, volcanological—palaeoenvironmental studies in Victoria Land are shifting focus to include a search for evidence of the non-glacial periods, to see how the Mio-Pliocene climate affected the entire temporal landscape. Initial results indicate that non-glacial conditions are indeed represented. Although the volcanic record is punctuated rather than continuous (sensu Smellie, 2018), acquiring a more holistic reconstruction of terrestrial environments in Victoria Land may be achievable.

Smellie, J.L. 2018. Glaciovolcanism – a 21st century proxy for palaeo-ice. In: Menzies, J. and van der Meer, J.J.M. (eds) Past Glacial Environments (sediments, forms and techniques), 2nd edition. Elsevier, Amsterdam, Netherlands, pp. 335-375.

Session01: Geological History of Victoria Land: Reviews and New Findings

The Ediacaran continental rifting overpritned by the Cambrian Ross orogeny along the East Gondwana margin: new evidence from the Lanterman Range eclogite in northern Victoria Land

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The Lanterman Range, situated at the central segment of the Wilson–Bowers terrane boundary in northern Victoria Land, is characterized by the occurrence of high-pressure metamafic rocks. The eclogite and its retrograde product are collectively named here as the Lanterman Range eclogite, and commonly occur as boudins enveloped by garnet–phengite-bearing quartzofeldspathic gneiss/schist. In this study, we correlated zircon growth history of pristine eclogite samples (E-1a and E-1c) to the Ediacaran rift-related magmatism and Cambrian arc-related metamorphism along the East Gondwana margin.
Mineral assemblages of the eclogite samples consist of garnet + omphacite + calcic/sodic-calcic amphibole + epidote + phengite + paragonite + rutile + quartz. Two distinctive *P–T* trajectories of prograde metamorphism were unveiled in the eclogites, and correlated to the metamorphic growth and/or recrystallization of the zircon mantle and rim domains during two episodes of subduction burial at *c.* 515 Ma and *c.* 500 Ma, respectively.
The SHRIMP U–Pb analyses on the zircon cores with subtle oscillatory zonation, acicular apatite inclusion and high Th/U ratios (0.34–0.67) yielded the weighted mean $^{206}Pb/^{238}U$ age of 591 ± 8 Ma ($t\sigma$), interpreted to date the crystallization of igneous protolith. The E-MORB to within-plate basalt affinity of the eclogites as well as quartzofeldspathic paragneiss country rocks suggest that their gabbroic protolith should be a spatial-temporal equivalent to the Ediacaran (*c.* 600–580 Ma) rift/passive-margin magmatic rocks of the Delamerian and Thomson orogens in eastern Australia. This is the first discovery of the Ediacaran rift-related magmatism in the Transantarctic Mountains to our knowledge. Our result is in contrast to the Cryogenian (*c.* 670–650 Ma) rifting followed by the Ediacaran (*c.* 590–570 Ma) arc initiation in southern Victoria Land and central Transantarctic Mountain. We tentatively suggest the oceanward propagation of rift center along the Australian-Antarctic margins and their diachronous tectonic inversion.

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Mesozoic volcanism in the Transantarctic Mountains

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Mesozoic volcanism in the Transantarctic Mountains marks the transition from the long-standing basin sedimentation of the Permian through Triassic Gondwana succession to the break-up of the supercontinent. It comprises two distinct, though overlapping, magmatic episodes, from silicic volcanism related to plate margin processes to basaltic magmatism associated with rifting, both having an Early Jurassic age. The former is recorded as distal airfall tuff and reworked tuff deposits, which are preserved as widely scattered sedimentary successions in the central Transantarctic Mountains (CTM) and Victoria Land. In the CTM they are interbedded with siliciclastic sandstones, arkoses, and conglomeratic sandstones, which infer a rift environment of deposition. In the CTM the strata, disconformable on Triassic beds, are up to ~235 m thick, but in Victoria Land have lesser thicknesses. In south Victoria Land (SVL), silicic shard-bearing strata occur only as a very limited outcrop at Coombs Hills and as clasts in overlying Mawson Formation (Ferrar Group) phreatomagmatic deposits at both Allan Hills and Ambalada Peak. In north Victoria Land (NVL), the silicic volcanic rocks (Shafer Peak Formation) are conformable on the siliciclastic Triassic-Jurassic Section Peak Formation, showing that the onset of volcaniclastic sedimentation was delayed relative to the CTM. For CTM beds, the rift setting, fine grain size, and rhyolitic composition suggest derivation from major volcanic centers along the Gondwana plate margin. In NVL the silicic shards are similarly attributed to distal centers, but there is no comparable evidence for a rift setting. In contrast to CTM, in NVL silicic strata of the Shafer Peak Formation are interbedded with basaltic phreatomagmatic deposits.

The onset of basaltic magmatism (Ferrar Large Igneous Province) is documented by pyroclastic rocks (Mawson and Prebble formations, Exposure Hill deposits), which were dominantly the result of phreatomagmatism. These beds, consisting of lahar, tuff, lapilli tuff, and breccia deposits, are up to 200 m thick in the CTM but have lesser stratigraphic thicknesses in Victoria Land. In addition, accumulations of volcanic debris, with a thickness of ~350 m, are present at Coombs Hills (SVL) and are interpreted as a huge (~30 km2) near-surface "phreatocauldron", which engulfed now-disoriented megablocks (100s m across) of Triassic strata. Similar diatremes filled by chaotic breccia blocks occur in NVL and CTM. At Allan Hills, adjacent to Coombs Hills, thick pyroclastic rocks are related to the "phreatocauldron" activity. Complex relationships are also exhibited in NVL. Pyroclastic activity was, for the most part, abruptly replaced by quiet effusion of flood lavas (Kirkpatrick Basalt), possibly the result of depletion of groundwaters that drove phreatomagmatism. The lava succession attains a ~900 m thickness in NVL. Basaltic pyroclastic intervals form a local constituent, as do thin tuff beds; lacustrine interbeds occur mainly low in the lava piles, but a significant interbed near the top of the succession separates the two Ferrar compositional types. One forms 99% of the province and has a coherent range of chemistry, whereas the remaining 1% has a restricted and highly evolved composition. U/Pb age determinations on zircon provide a best estimate age of 182.7 Ma for Ferrar magmatism. Lavas range from 1 to 220 m in thickness, the latter undoubtedly due to ponding; most are in the range 10-100 m and the thick flows may also be ponded. Vents have not yet been identified. Contemporaneous sills intruded into Devonian-Triassic Beacon strata are the most extensive expression of the magmatism, and in the thickest Beacon sequences the cumulative sill thickness may reach 1500 m. The Basement Sill in the Dry Valleys (SVL) has provided important insights into magmatic processes in hypabyssal and plutonic bodies. The relatively slow cooling has preserved details of the processes of compaction and of the interstitial liquid segregation features that are generally lost in more slowly cooled and thoroughly annealed layered basic intrusions. The

Basement Sill is exposed over an area of 10,000 km2 and a possible feeder vent identified; magma was expelled from this feeder as a series of orthopyroxene-bearing tongues. No other feeders have been identified. Regionally, zeolite-grade metamorphism in the Beacon strata is attributed to intrusion of sills. In addition, a Cretaceous thermal event is recorded in the paleomagnetism, Ar-dating, and secondary minerals of the lavas. The possibility exists of a post-Ferrar stratigraphic section, which has been completely eroded away.

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Lithostratigraphy, biostratigraphy, and geochronology of the Bowers Supergroup in northern Victoria Land, Antarctica

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Basement rock of the northern Victoria Land consists of three terranes (Wilson, Bowers, and Robertson Bay terranes) accreted during Ross Orogeny associated with subduction of Paleopacific plate beneath the Antarctic continent. The lower Paleozoic successions in the Bowers Terrane, named Bowers Supergroup, was subdivided into Sledgers, Mariner, and Leap Year groups in ascending order. The Mariner Group is characterized by various lithologies and ample occurrence of fossils. It enables reconstructing depositional environments and providing stratigraphic framework of the lower Paleozoic northern Victoria Land. Korea Antarctic Geological Expedition (KAGEX) have conducted field work and facies analysis in the Eureka Spurs, the type section of the southern part of the Mariner Group. The Spurs Formation consists of fissile mudstone, thin-bedded sandstone, breccia, diamictite, and oolitic grainstone facies, which form a coarsening upward trends. Sedimentary structures suggested that some strata in the middle part of the Eureka Spurs section were overturned. And detailed sampling and morphologic lineage of trilobites are in accordance with this overturn structures. The Eureka Formation conformably overlying the Spurs Formation consists of mudstone, bioturbated mudstone, wave ripple laminated sandstone and transitionally changes into fluvial siliciclastics of the overlying Leap Year Group. Trilobite fossils from the Spurs Formation indicate that the formation was deposited no later than 503 Ma. The overall facies succession of the Mariner Group suggests regressive facies succession from deep sea and continental shelf to shoal environments, which represents a closure of a back-arc basin formed by subduction of Paleopacific plate.

Detrital zircons from six sandstone samples of the southern part of the Bowers Supergroup were separated and SHRIMP U-Pb ages were acquired. Zircon age populations of the Sledgers and Leap Year groups show prominent peaks of Ross age (480-550 Ma). The second largest peaks represents Grenvillian age (900-1350 Ma). Wide spread older zircon ages ranging from 1400 Ma to 3300 Ma are designated as cratonic ages. These patterns in detrital zircon age population is similar to those of metasedimentary and sedimentary rocks of Wilson Terrane and central Transantarctic Mountains. The youngest zircon dates in the Sledgers Group are 493 and 495 Ma. On the other hands, zircon ages of sandstones from the Mariner Group shows meager development of Ross age peaks and characterized by wide peaks in 1200-1500 Ma range. This difference in detrital zircon ages are interpreted as changes in drainage system in the hinterland due to tectonic movement or changes in sedimentary distribution system in the basin. Discrepancy in youngest zircon dates of the Sledgers Group and depositional age of the overlying Mariner Group is problematic. For better understanding of this stratigraphic change in detrital zircon age distribution, those in the northern part of the Bowers Terrane (Reilly Ridge, Edlin Neve) are to be analyzed.

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Early Paleozoic linkage between the Ross Orogen, Antarctica, and Korean Peninsula: A perspective from U-Pb detrital zircon ages of Cambrian–Ordovician sandstones in the Taebaeksan Basin, Korea

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The early Paleozoic paleogeography of various terranes in the East Gondwana, including the North China Craton (NCC), remains contentious partly because of the lack of studies integrating geochronological, biogeographic, and tectonic data sets. Here we review in-situ U-Pb ages of detrital zircons available from the Cambrian–Ordovician sandstones of the Taebaek and Yeongwol groups in the Taebaeksan Basin, Korea. Both groups consist of platform shelf sequences and contain trilobite assemblages diagnostic of the NCC. Detrital zircons of sandstones from the Taebaek Group reveal three distinct types of Precambrian age distribution, respectively characterized by: (1) double peaks at ~1.87 Ga and 2.5 Ga typical for the NCC; (2) minor to moderate population of Mesoproterozoic zircons in addition to the double peaks; and (3) the predominance of Mesoproterozoic and Neoproterozoic zircons without the double peaks. Type 3 is also prevalent in fine-grained sandstones of the Yeongwol Group, suggesting that both groups of the Taebaeksan Basin shared the same provenance for Neoproterozoic detrital zircons. The marked contrast between type 1 and 3 patterns reflects a significant shift in provenance from proximal to distal sources. In addition, all formations in the basin except for the lowermost unit contain the Cambrian–Ordovician zircon population whose U-Pb ages apparently decrease up-section from ~510 Ma to ~485 Ma. Such a variation as well as syn-depositional age of the youngest population is best accounted for by sedimentary influx from contemporaneous igneous rocks. In conjunction with arc-related whole-rock geochemistry and juvenile Nd isotopic signature, we interpret that early Paleozoic detrital zircons represent first-cycle detritus supplied for > 25 m.y. from a peri-NCC magmatic arc. Such an arc complex may include the proto-Japan arc developing around the proto-Pacific Ocean in conjunction with the Terra Australis or Ross-Delamerian Orogen. Thus, we suggest that research efforts in northern Victoria Land play an important role for understanding geological and tectonic histories of the Korean Peninsula as well as the Antarctica and adjacent landmasses.

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Hydrothermal fluids and fracturing along faults in the Rennick Graben (northern Victoria Land, Antarctica): a microstructural study

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The present day tectonic setting of the Transantarctic Mountains (TAM) in northern Victoria Land (Antarctica) is dominated by km-scale WNW-ESE trending lineaments running from the Pacific Ocean to the Ross Sea, which show a well-documented long history of tectonic reactivation from the Paleozoic to Recent time. At places, the damage zones of these faults are associated with various volumes and degrees of syn- to post-tectonic hydrothermal alteration and secondary minerals formation. Understanding the interplay between syntectonic hydrothermal fluids and deformation along the faults is fundamental as it affects the physico-chemical properties of the fault system and influences the partitioning of deformation. Moreover it could help to frame the temporal evolution of the fault into the geodynamics scenario of the TAM.

Here, we focus on two detachment zones (DZ) located in the Lanterman Range on the eastern shoulder of the Rennick Graben Auct. , which are related to the aforementioned lineament system. We performed multiscale structural investigations of the fault rocks (from field- to micro-scale), which are characterized by an association of proto-mylonite, cataclasite and ultracataclasite including minor pseudotachylyteand secondary formation of epidote, prehnite and calcite within the fault rock matrix and in microveins.

The host rock is a Cambro-Ordovician granitoid (Granite Harbour Intrusive Complex) mainly composed of mm-sized euhedral to subhedral crystals of K-feldspar, plagioclase, biotite and quartz (plus minor zircon and apatite). The studied DZ are about 2 cm-thick with a 2-3 cm-thick altered wallrock cut by tiny epidote and calcite veins. In the wallrock, magmatic minerals are partially to completely replaced by saussurite and sericite, albite, chlorite, epidote, prehnite and minor sphene. The DZ core consists of crosscutting mm-thick layers and superposed slip zones and recrystallized pseudotachylyte injection fault-veins. At microscopic scale, we divided between dark-green (DG) and light-green (LG) ultracataclasite layers; XRD, electron microprobe (SEM-EMPA) and EBSD (Electron Back Scattered Diffraction) analyses revealed: (i) DG layers are low-grade mylonite to ultracataclasite mainly consisting of mm-sized K-feldspar porphyroclasts within a fine grained micron-sized quartz and plagioclase matrix partially derived from dynamic recrystallization and/or fracturing of primary magmatic minerals. K-feldspar porphyroclasts show strain-induced myrmekite and evidences of crystal-plastic deformation. Deformed K-feldspar and quartz are partially replaced by two generations of syn- to post-tectonic epidote;– (ii) LG layers contain fragments of the DG ultracataclasite and of single crystals of deformed K-feldspar, albite, quartz and epidote within a matrix rich in newly formed micron-sized prehnite. Like epidote, prehnite is syn- and post-tectonic. Recrystallized pseudotachylyte injections occur in the slip zone at the boundary between the fault core and the wall rock.
The studied DZ show a polyphase deformation history with superposed events of fluid-assisted reactivation in upper crustal levels at the brittle-ductile transition zone for a granitic rock. Thin microfractures and/or localized low- to medium-grade proto-mylonitic zones were potential precursor

for syntectonic hydrothermal fluid infiltration and successive cycles of deformation, sealing and healing processes along the detachment zones. The fault rocks were sealed and indurated by epidote and prehnite and this favoured a seismic behavior during the exhumation of the fault zone (pseudotachylyte injections veins). The multiple deformation events with formation of Ca-rich alteration phases, i.e. epidote, prehnite, and calcite, points to syntectonic hydrothermal Ca-rich fluids that recorded changing T (under 350 deg C) and fCO2. The possible origins of the fluids in the geodynamic scenario of Victoria Land are discussed.

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The youth of the Transantarctic Mountains: Late Mesozoic highland or sedimentary basin?

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The Transantarctic Mountains (TAM) are exposed as elongated fault-segmented plateau representing the world's longest extensional mountain chain. Their formation is commonly referred to the rifting of the Cenozoic West Antarctic Rift System but mechanism, course, and timing of uplift are debated controversially. Scenarios of TAM uplift can be grouped into three general mechanisms (or combinations of them), derived primarily from geophysical data and their geodynamic modelling, structural geology data, and thermochronological age information: (i) isostatic response to rifting/normal faulting, (ii) thermal uplift, and (iii) collapse of a Mesozoic highland. Each of the three hypotheses appears realistic in the light of primary geophysical data, but the compatibility with the geological record, especially sedimentary, thermochronological, and structural geology data, and geomorphological observation, and resulting initial landscape constraints have not been tested yet thoroughly.

The TAM mainly consist of basement rocks capped by a late Paleozoic erosion surface, the Kukri surface. The Kukri is partially overlain by a diachronous Devonian – Early Jurassic terrestrial sedimentary sequence. Permo-Triassic coal seems, a Glossopteris-dominated floral assemblage, ripple marks, braided river sediments, lake deposits and other features within these strata indicate deposition in shallow marine, fluvial and lacustrine environments. Both basement and sedimentary cover are topped in places by ~180 Ma lava flows including pillow lavas and subaerial and subaquatic volcanoclastic deposits.

The thermochronological record of the TAM comprises more than 600 apatite fission track and (U-Th-Sm)/He ages and associated proxies. Thermochronological ages from low elevations are 100°C, and Cenozoic cooling. Thermal history modelling dates the onset of cooling in the northern Ross Sea segments of the TAM at ~35 Ma. Such a thermal history can only be explained with the existence of a sedimentary basin between Jurassic and Eocene times. Numerical modelling further reveals an increased Jurassic geothermal gradient that stabilized at ~25°C/km since the Cretaceous. Cenozoic exhumation and basin inversion was accompanied by tectonic and volcanic activity in both TAM and Ross Sea and terminated with the re-exposure of the Kukri. Combined sedimentary, stratigraphic, paleontological, petrological, thermochronological, and geomorphological evidence collectively imply a Mesozoic – Paleogene lowland setting near sea level for the present TAM. This setting necessarily has to constitute a basic constraint for any geodynamic model of the TAM uplift and provides the main test criteria for the proposed uplift mechanisms.

(i)The uplift model based on faulting and rifting would favor thickened continental crust to account for rifting and thinning of the Ross Sea but does not require any particular pre-TAM landscape setting. It would coincide well with the initial lowland setting adjacent to a failed passive margin, resembling a geotectonic setting similar to the Basin and Range Province.

(ii)The second uplift scenario relying on heat flow variation would also be generally compatible with long-lasting Mesozoic extension and could account at least for some part of uplift. A critical aspect would be only the just moderate Cretaceous and Cenozoic heat flow observed in the TAM.

(iii)A late Mesozoic highland plateau consisting of overthickened continental crust seems the most elegant option to account for intense Cenozoic extension of the Ross Sea and may fit well the underlying geophysical data. However, this hypothesis is in striking contrast to both the Mesozoic

lowland plane setting proven by all basic geological observation, and the burial of Kukri peneplain and Permian – Jurassic deposits indicated by thermochronological data, and hence needs to be abandoned.

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REGGAE: Tectonic history of the Rennick Graben (Antarctica) - International effort for Geology and Aeromagnetic Exploration

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Multiple rifting between East and West Antarctica in the late Meso- and Cenozoic has led to the formation of the West Antarctic Rift System (WARS), one of the largest continental rift systems worldwide. The Transantarctic Mountains (TAM) represent the uplifted western shoulder of this asymmetric rift. Rapid uplift of the TAM initiated ca. at the Eo-Oligocene boundary – notably coinciding with global climatic deterioration – after deposition of large amounts of sediments in a long-lived Mesozoic to early Paleogene basin (the Mesozoic Victoria Basin (MVB). Uplift has led to (i) tectonic inversion of this basin, (ii) erosion of the former basin-fill and (iii) deposition of the detritus into the evolving rift basins of the WARS. Direct evidence of the MVB is not preserved in the rock record but its existence has been postulated based on thermochronological modelling; nevertheless, there is still significant controversy on both origin and evolution of the TAM. The basement of the TAM originated from orogenic processes along the Palaeo-Pacific active continental margin of East Gondwana, in late Ediacaran to Palaeozoic times, and the formation of highly anisotropic crust that is susceptible to reactivation by later tectonism. This is of particular interest in the East-West Antarctic boundary region, where reactivation of pristine former structures may have influenced and/or triggered the separation of Antarctica and Australia during the Gondwana break-up. Here, we focus on the Rennick Graben (RG) region in northern Victoria Land (nVL), which provides key views into the reactivation of these inherited structures. While the northern segment of the RG is well established, its southern continuation towards the Ross Sea and possible connections to the WARS, the Wilkes Subglacial Basin (WSB) in the western ice-covered hinterland of the TAM or the Adare Trough (AT) in the Pacific Ocean, is still disputed. Understanding the effects and timing of geodynamic processes that reactivated the inherited architecture of nVL is an important step to better define this sector of the TAM and to establish links with the evolution of the WARS and the opening of oceanic gateways between Australia and Antarctica.

The aim of the international REGGAE project is to better constrain the structural architecture of the RG, its evolution in space and time, and its potential links with the WARS, WSB and/or AT. REGGAE is based on a multi-methodological approach, including structural geology, petrology, geo- and thermochronology and aerogeophysics (magnetics, gravity, radar). The RG has been linked to early stages of the WARS rifting within a pull-apart scenario related to late Mesozoic left-lateral strike-slip tectonics, or alternatively as a pure Cenozoic narrow extensional-transtensional structure that formed in response to NW-SE trending right-lateral shear systems transecting nVL from the Pacific Ocean to the Ross Sea. Results lead us to hypothesize that the present tectonic depression of the RG developed in a crucial position within nVL crust, with inherited anisotropies derived from Paleozoic to Mesozoic geodynamic processes at the Palaeo-Pacific margin of East Gondwana. Data suggest that the nVL crust was subject to polyphase brittle to semi-brittle tectonics under varying settings (e.g., strike-slip- vs. extension-dominated) since the middle/late Mesozoic. Furthermore, the presence of syn-sedimentary deformation in the late Permian strata, as well as similarly oriented strike-slip shear systems of clear late-Ross-orogenic age, favour a rather complex history of

repeated reactivation of inherited structures throughout the Phanerozoic.

Session01: Geological History of Victoria Land: Reviews and New Findings

Reconstruction of paleoenvironmental change through paleo-dendrochronology analysis of a Triassic polar forest in Allan Hills (Antarctica)

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Dendrochronology is a widely used geochronometer and a basis for the reconstruction of the climatic history of the historical period. Application of dendrochronologic methods, however, is relatively unexplored for fossil wood in deep time stratigraphic successions. Here, we report the results of dendrochronology applied to thirteen Middle Triassic fossil wood samples from the Victoria Group (Beacon Supergroup, South Victoria Land, Antarctica).
In the Permian-Triassic Victoria Group, and in many of the contemporaneous outcrops on Gondwana are remains of plant life as fossilized leaves, roots and fossil trunks. In the Allan Hills a massive accumulation of fossil wood is well preserved in the fluvial sandstones of the Triassic Lashly Formation.
The fossil trunks are exposed in three stratigraphic levels and are concentrated due to the transport by a fluvial system (maybe in a flood, forming logjams), the wood colour is predominantly black and is at least partially silicified. Some of these logs reached some meters of length. The internal anatomy of the wood lacks evidence of bark, shows good preservation of tracheid and ray cells, and some specimens have preserved the pith. In some of the samples, morphologic characteristics consistent with saprotrophic fungal alteration are observed.
The dendrochronologic analysis of these samples result in a chronology of 237 years for this Triassic succession, the longest chronology so far for fossil samples. It is supported by replication of ring width growth variations from between two to four specimens at any given increment in the chronology. Paleoclimate, and perhaps paleoecologic, inferences can thus be drawn from this chronology.
The ring width index (RWI) shows a trend of 20-25 years as a periodical fluctuation in growing conditions; the RWI trends of this analysis are remarkably similar to another recent Middle Triassic dendrochronology study applied to the same deposit, suggesting the strength and replicability of this method as applied to fossil wood. Moreover, 6 of 11 samples have pith and their positions in the chronology time line show that the trees originated randomly over time, excluding the possibility of a catastrophic event leading to the deposition of the wood. This trend is different to the trend show from Permian samples, where the cycling is about 50 years and the RWI amplitude is significantly less than that of the Triassic, furthermore the growth rings appear different, with the Permian specimens showing a wider mean width than the Triassic samples.
We speculate that the differences in RWI, and frequency of complacent growth intervals, appears due to the different climatic condition from Permian to Triassic. Indeed, across the Permo-Triassic Boundary global average temperatures increased (probably also atmospheric CO2 increase) and the landscape is interpreted to change to more stable landscapes based upon paleosol development, thickness, and abundance.
A paleoecologic change also occurred in the transition from the Late Permian to Middle Triassic, involving plant migration at different latitudes. In addition, the latitude of the study area shifted from ~80ºS in the Late Permian to ~65ºS in the Triassic, potentially changing the seasonal difference light conditions, temperature, and rainfall.

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Preliminary reconnaissance of the Grenville basement and its Ross perturbation: contrasting zircon and monazite ages in a migmatitic gneiss from the Priestley Schist, northern Victoria Land, Antarctica

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Detrital zircon from (meta)sedimentary rocks of the Wilson, Bowers and Robertson Bay Terrranes in northern Victoria Land, Antarcitca commonly shows a range of U–Pb ages subdivded into the Pacific-Gondwana (~500–700 Ma), Grenville (~900–1,300 Ma), and cratonic (>1.6 Ga) age population. Moreover, the provenance of the detrial zircon as well as the presence of Precambrian basement rocks in northern Victoria Land remain largely unknown. We investigated the U–Pb isotopic compositions of zircon and monazite in a migmatitic gneiss sample in the Priestley Schist, and discovered an extraoridnary age distribution of zircon and a contrast in crystallization age of the chronometers. The sample consists of the leucocratic and melnocratic layers with biotite, plagioclase, K-feldsapr, and quartz, as well as accessory apatite, zircon and monazite. The former contains medium-grained crystals showing microstructures such as myrmekite, lobate grain boundary, and undulatory extinction, indicative of high-T deformation subsequent to partial melting, whereas the fine-grained latter is rich in biotite and quartz.

Zircon crystals in the sample are generally subhedral, and are heterogeneous in internal zonation. The U–Pb isotopic ages of zircon were analyzed using a SHRIMP machine, and total 51 spot analyses were carried out from 31 zircon crystals. The majority of the crystals shows concentric to oscillatory zonation, and their spot analyses cluster around ~1.2 Ga in the Tera-Wasserburg concordia diagram, apart from minor xenocrysts of ~1.8 Ga, ~1.6 Ga, and ~1.4 Ga. The weighted mean 206Pb/238U age of the Late Mesoproterozoic zircon was calculated as 1,165 ± 9 Ma (tσ; MSWD=1.87). In contrast, the U–Pb isotopic compositions of monazite from 14 spot analyses gave an identical apparent age within uncertainty, and yielded the weighted mean 206Pb/238U age of 491 ± 4 Ma (tσ; MSWD=1.57). On the basis of the petrologic and geochronologic features, we prelimiarily conclude that melt crystallization of the migmatite took place during the Late Mesoproterozoic, followed by the low-P metamorphism during the Late Cambrian.

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Session02: Structure, evolution, and heterogeneity of Antarctica's continental lithosphere

Combining satellite and aeromagnetic data in Antarctica – pitfalls and opportunities

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Large parts of Antarctica are covered by aeromagnetic surveys that have been recently compiled within the international ADMAP 2.0 project, which can be used for tectonic interpretations and for magnetic source depth estimates. However, the accuracy of the long wavelength part of survey data is limited due to various reasons, e.g. survey extension, IGRF/DGRF correction, levelling or data merging. Therefore, satellite data or global models are often used to replace the long-wavelength part, despite a spectral gap between satellite and survey data. The new generation of satellite data can help better define the long-wavelength part of the magnetic anomaly field, especially with the availability of new models based on the Swarm satellite mission.

We use both a satellite derived dataset and a combined dataset to analyse the lithospheric sources of magnetisation for the Antarctic continent. A step-wise approach is introduced, where both data sets are used within their sensitive spectral range.

We demonstrate that in a cratonic setting like East Antarctica estimates of deep magnetic sources can be very inaccurate and should therefore only be interpreted with great caution in terms of Curie isotherm depth, for example. Furthermore, the use of such estimates alone in deriving geothermal heat-flux is limited. In order to properly assess Curie depth variations and their tectonic significance, the magnetic analysis needs to be linked to independent thermal models of the lithosphere either by forward or inverse modelling.

An alternative approach is to use the magnetic anomalies to indirectly trace the extent of subglacial geological provinces, which potentially have different thermal properties. Such an approach, especially if based on cluster analysis together with the gravity field, can provide information that can be exploited by stochastic inversion of multiple data sets.

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A 3D model of Antarctica’s lithosphere from integrated and self-consistent modelling and its implications for GIA

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We present a 3-dimensional model of the Antarctic lithosphere, integrating satellite gravity gradient data and petrological modelling in a self-consistent manner. Current studies on the lithospheric structure of the Antarctic continent contradict each other in many cases, depending on the applied geophysical method. This has large implications for considerations regarding the isostatic state of the continent. Moreover, hypotheses on the geodynamic history of interior Antarctica predominantly rely on geophysical findings. Seismological methods, however, suffer from a limited station coverage and ice reverberation, whereas potential field methods, such as gravity studies, are inherently non-unique.

By modelling densities and seismic velocities in a consistent way, also accounting for thermodynamically stable mineral phases of rocks under in-situ pressure and temperature conditions, we are able to compensate for the sparseness of data in Antarctica and reduce inconsistencies and ambiguities of separate geophysical methods to a large extent. Gravity gradient data from ESA’s GOCE satellite mission are used to constrain the density distribution within the lithosphere. Seismic estimates serve as a benchmark for the robustness of our model. Its thermal field is taken to derive the mantle’s viscosity for glacial isostatic adjustment (GIA) modelling. We find that viscosity values at shallow depth (150 km) in the south part of the Ross Sea, part of the Antarctic Peninsula, and East Antarctic coastal areas are lower than previous estimates of 3D mantle viscosity. This increases the importance of late Holocene ice mass changes in these areas and underlines the requirement of improving mantle viscosity estimates from a combination of geophysical methods.

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The early Mesoproterozoic Filla Series in the Rauer Islands: a possible fragment of the long-lived Fraser–Fisher–Ongole oceanic realm

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The Rauer Islands in eastern Prydz Bay coast include Archaean and Proterozoic protoliths.
Previous studies concentrated on Archaean rocks, while Proterozoic rocks drew less attention. The Filla Series is a high-grade metamorphic association composed of strongly sheared mafic to intermediate granulites (presumably metavolcanics) and garnet-biotite paragneisses. Our U–Th–Pb (SHRIMP) zircon dating on 3 granulites revealed magmatic protolith formation at ca 1500 Ma (49 point upper intercept, 5 concordant analyses), and metamorphic overprints at ca 1000 Ma (9 concordant analyses) and ca 530 Ma (a lower intercept, 10 concordant analyses).
Various paragneisses contain detrital zircons ranging in age from Palaeo- to supposedly Neoproterozoic. The Filla Series was intruded by ca 1150 Ma metagranitoids and metagabbro.

The chemical compositions of rocks correspond to basalt (strongly predominate), basaltic andesite, and rare andesite. All rocks form a strongly fractionated (#mg = 35–65) tholeiitic association. Three geochemical rock groups may be distinguished. Group 1 rocks have smooth spiderdiagram patterns similar to the E-MORB or OPB. Group 2 rocks show moderate LILE and LREE enrichment and pronounced Nb–Ta troughs with Nb/La = 0,1–0,5. Geochemical features of group 2 rocks correspond to subduction-related arc basalts. Group 1 and group 2 rocks occur as intercalated beds or members between a few meters to 20–50 m thick. Group 1 rocks have higher Nb/Th, Ti/Zr, and Nb/La and lower Th/Yb, Zr/Nb, Ce/Y, and LaN/NbN than group 2 rocks suggestive of derivation from different mantle source. Group 3 rocks represent a few beds (sheared dykes?) and display HFSE-enriched compositions with no Nb–Ta or minor troughs; these rocks have geochemical features suggestive of derivation in within-plate environments. Nd isotopic compositions of group 1 and group 2 rocks are rather primitive with epsilon(1,5) = 2.8–4.5 and T(DM) model ages 1.76–1.95 Ga. Intercalation of rocks derived from E-MORB upper mantle (group 1) and subduction-related melts (group 2) may be explained by contemporaneous drainage of variously modified mantle sources occupying different lithospheric horizons. Tholeiitic magmatism at ca 1500 Ma may indicate magmatic arc related to oceanic basin which was manifested by somewhat older juvenile additions at Yilgarn Craton margin (1700−1650 Ma, Biranup Zone, Kirkland et al., 2011, followed by juvenile Fraser Complex formation in mid-Mesoproterozoic) and possibly at Dharwar Craton margin (1800−1600 Ma, Ongole Domain, Dasgupta et al., 2017) or within the Central Indian Tectonic Zone (ca 1640–1450 Ma, Chakraborty et al., 2018). Nearly co-eval (ca 1480 Ma) magmatic arc has been distinguished in Mt Brown located 300 km eastward (Liu et al., 2016). Somewhat younger magmatic arc (1400−1300 Ma, Fisher Terrane, Mikhalsky et al., 2001) has been defined in Prince Charles Mountains. Thus Filla Series may complement the history of a long-lived vast Paleo- to Mesoproterozoic oceanic basin.

At the same time the observed geochemical features of group 2 rocks may be explained by extensive crustal contamination or melt mixing. The contamination model would imply derivation in within-plate environments and leading role of extension (Columbia break-up?).

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Microstructures of peridotites from the Mount Melbourne, Antarctica

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Microstructures of mantle xenoliths are investigated to understand internal structure and evolution of mantle beneath the Mt. Melbourne, Antarctica. Massive peridotites are characterized by abundant undulose extinction of olivine, bent cleavage traces of orthopyroxene and interstitial spinel. Chemical compositions of spinel and olivine suggest the low degree of melting. The olivine CPOs of six peridotites are acquired by rotation of [100] and [010] to be paralleled to lineation and foliation, respectively, after EBSD analysis. The CPOs of the analyzed olivine in peridotites are subdivided into D- and A-type based on Fabric Index Angle (FIA) methods (Michibayashi et al., 2016, EPSL). Temperature and pressure conditions are calculated as >900 °C and >9 MPa by two-pyroxene thermometer and grain size piezometer, respectively. Absent water content in olivine detected by FTIR is concordant with results of the FIA analysis. Abundant intracrystalline deformation features combined by low degree of melting may suggest the existence of partial melting beneath the West Antarctic Rift System. Therefore the occurrence of low-velocity zone beneath the Mt. Melbourne can be explained by seismic anisotropy of olivine in the massive peridotites.

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Corroboration of a branched Pan-African suture in Princess Elizabeth Land

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East Antarctic shield's (EAS) affinity to other continents plays a crucial role in supercontinent reconstructions and our understanding of continental evolution. One largely unexplored segment of EAS is Princess Elizabeth Land (PEL). Recent geophysical data revealed a Pan African suture marking the boundary between Indian and Australian affinity terrains in PEL.
Ice free outcrops in PEL include coastal fringe of east Prydz Bay in form of island groups, peninsulas and bluffs and an inland group of scattered mountains and nunataks collectively called Grove mountains. Brattstand bluff- Svenner islands- Larsemann Hills constitute a significant section of PEL coastal exposures that were believed to be metamorphosed to granulite grade during the 1100-1000 Ma and later imbibing a Pan African thermal overprint. Our investigations of this terrain suggest existence of a relict ~800 Ma orogeny overprinted by a strong Pan African granulite grade metamorphism with a coast parallel structural trend.The Pan African event has been established as the prominent metamorphic event of the area. This is supported by the recent magnetic data. A high magnetic anomaly is evident in coastal area of PEL.Connecting geological data with the magnetic data suggests presence of a branch of the Pan African suture along the PEL coast. Petrographic and geochronological data is interpreted in conjunction with similar data from Eastern Ghat Mobile Belt (EGMB) and Rengali domain to refine the India-Antarctica paleogeographic connection and a new evolutionary history for this sector.

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Crustal Evolution of the Archean Napier Complex

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The Napier Complex forms part of the East Antarctic Shield and consists predominantly of gneisses, metamorphosed at ca. 2.5 Ga under granulite-facies to UHT conditions. Some of the oldest rocks on Earth, with zircon ages approaching 4.0 Ga, are found as protoliths to felsic orthogneisses at Mount Sones and Gage Ridge in the Tula Mountains [1] of Enderby Land and in Kemp Land, 170km to the east, at Aker Peaks [2]. The relationships between protoliths of widely differing ages across the Napier Complex are little understood, having been largely obscured by the intensity of ca. 2.5 Ga orogenesis.

As a further step towards identifying crustal domains across the Napier Complex, five orthogneiss samples from the eastern Tula Mountains were dated by zircon U-Pb Secondary Ion Mass Spectrometry (SIMS). The samples consist of quartz monzonitic (TME01) and granitic (TME03) gneisses from Mount King; a quartz monzonitic gneiss from Budd Peak (TME05); and trondhjemitic (TME04) and dioritic (TME07) gneisses from Mount Jewell. Two (TME01 and TME05) belong to the Y-HREE depleted group of Sheraton and Black [3] and have low Nb contents typical of medium to high-pressure TTG granitoids [4]. The remaining three samples (TME03, TME04 and TME07) are Y-HREE undepleted, with higher Nb-Ta contents. Two geochemically different samples (TME04, TME05) contain magmatic zircon with ca. 3.7 Ga ages, which are interpreted as protolith ages of the gneisses. The protolith age of dioritic sample TME07 is estimated at ca. 3.55 Ga, whereas those of samples TME01 and TME03 are between 3.0–2.8 Ga.

This study reveals that both Y-HREE depleted and undepleted protoliths formed during the Eoarchean and Mesoarchean eras, and indicates that each generation of magmatism involved remelting and recycling of different crustal components. It shows, therefore, that there was not just a single generation of crust during either era. Moreover, contrasting HREE patterns shed light on the conditions of magma genesis, implying that melting occurred at differing pressures. This highlights the complex nature of the Archean crust, resembling modern subduction settings. Research into the age and geochemistry of other regions within the Napier Complex is ongoing, with the aim of shedding new light on the development of crust in the early stages of the Earth's history. In addition, Lu-Hf data have been collected from Aker Peak samples and these confirm the antiquity of the rocks, although Hadean model ages have yet to be recorded.

Geoscience Australia is thanked for access to the sample. The research was conducted with the financial support of NCN grants UMO2016/21/B/ST10/02067 to MAK.

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New magnetic data processing methods give better data for better geology

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Antarctic geology poses the substantial challenge of lack of exposed rocks, meaning that much of the geology of the continent is understood from geophysical data, in particular airborne gravity and magnetic data. These data are also challenged, in that Antarctic regions are not conducive to easy data collection. Although individual data may be high quality, data are often sparse, are collected across long time-scales and at different heights above the bedrock surface topography rendering interpretation difficult. Quantitative interpretation is especially difficult. Here we present a new magnetic data collection workflow for sparse and four-dimensional data (MaDCoWS-4D) that is also generalisable to gravity data. The correction procedure involves a series of corrections, including initial QC, correction for geomagnetic field variations, as described in POMME magnetic models, a novel base-station correction method for multiple distant base stations, and finally a topographic correction using 3D inversion, allowing survey data to be re-calculated on pseudo-draped and constant elevation surfaces. Application of these steps to the regional-scale ICECAP survey results in a demonstrated reduction in non-geological content in the magnetic field data, and correspondingly, a higher confidence in the ability to map geology from these data.

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Geophysical characteristics and tectonic evolutions of Jane basin, Weddell Sea

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Jane Basin is a deep-sea basin along the SE margin of the South Orkney Pleateau , West Antarctica. little attention has been paid to it because of the remote and the ice-covered. During the 34th Chinese Antarctic Expedition, a lot of data of gravity, magnetism, multi-beam, shallow bottom profiles and multi-cannels seismic have been obtained by R/V Xiangyanghong01, around south Orkney microcontinent and Jane basin. Maps of free-air gravity anomalies, bouguer gravity anomalies, ΔT magnetic anomaly and Crustal Thickness are compiled. The results show that Jane basin has the different characteristics of gravity field and crustal thickness compared with those of Dove basin and Scan basin, thought they are just only separated by the south Orkney trough.

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Observations of the azimuthal dependence of normal mode coupling at the South Pole and its nearby stations: Insights into azimuthal anisotropy beneath the Transantarctic Mountains

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Normal mode coupling pair 0S26–0T26 and 0S27–0T27 are significantly present at the South Pole station QSPA after the 2011/03/11 Mw9.1 Tohoku earthquake. In an attempt to determine the mechanisms
responsible for the coupling pairs, We first investigate mode observations at 43 stations distributed along the polar great-circle path for the earthquake and observations at 32 Antarctic stations. I rule out the effect of Earth's rotation as well as the effect of global large-scale lateral heterogeneity, but argue instead for the effect of small-scale local azimuthal anisotropy in a depth extent about 300 km. The presence of quasi-Love waveform in 2–5 mHz at QSPA and its nearby stations confirms the predication. Secondly, We analyze normal mode observations at the South Pole location after 28 large earthquakes from 1998 to 2015. The result indicates that the presence of the mode coupling is azimuthal dependent, which is related to event azimuths in -46 degree to -18 degree. We also make a comparison between the shear-wave splitting measurements of previous studies and the mode coupling observations of this study, suggesting that their difference can be explained by a case that the anisotropy responsible for the mode coupling is not just below the South Pole location but located below region close to the Transantarctic Mountains (TAM). Furthermore, more signals of local azimuthal anisotropy in normal-mode observations at QSPA and SBA, such as coupling of 0S12-0T11 and vertical polarization anomaly for 0T10, confirms the existence of deep anisotropy close to TAM, which may be caused by asthenospheric mantle flow and edge convection around cratonic keel of TAM.

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Permian-Triassic rifting shaped subglacial landscape of western Wilkes Land, East Antarctica

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Sedimentary basins under the East Antarctic Ice Sheet preserve the record of poorly-understood plate tectonics and geodynamic processes that have shaped the East Antarctic landscape. These basins host some of the largest glacial catchments in East Antarctica and are key to understand how tectonic forcing and Cenozoic glacial activity have combined to drive topographic change through time.

In this study, we investigate the tectonic origin and erosional history of one such subglacial basin in western Wilkes Land, the Knox Rift, to improve our knowledge of tectonic and topographic evolution in the region. Previously, modelling of airborne gravity and magnetic data suggested that the Knox Rift may constitute a Mesozoic rift basin. Its flanks exhibit elevated and rugged topography (~1200 m), while its central depression hosts the Denman and Scott Glaciers, two of the largest ice streams in the region.

We quantify the timing of rifting and the magnitude of regional uplift and erosion using a combination of low temperature thermochronology from outcropping basement rocks and detrital zircon U-Pb analysis of glacial moraines sourced from the Knox Rift. Time-temperature modelling of zircon and apatite (U-Th)/He basement ages is consistent with exhumation and erosion during rifting in the Permian-Triassic (280-220 Ma), with 3 younger (200-170 Ma) apatite (U-Th)/He ages indicating rift reactivation during the Early Jurassic. U-Pb detrital zircon geochronology and Pb-loss modelling also confirms the presence of a sedimentary infill in the Knox Rift that is Permian in age.

Our new data suggest that the main rifting phase in the Knox Rift is consistent with continental extension in East Gondwana during the Permian-Triassic, which we interpret may have largely affected this sector of East Antarctica. We propose that the present-day topography of this region is – at least at longer wavelengths – tectonically-driven by Permian-Triassic rifting. Average slow erosion rates (~2.6 km since 250 Ma) support the preservation of topographic features since the cessation of Permian-Triassic rifting. The spatial correlation of younger Jurassic apatite (U-Th)/He ages with the Scott and Denman ice streams also suggest that Cenozoic glacial erosion may have exploited pre-existing tectonic/topographic features, thus supporting a tectonic control on the location of these ice streams.

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Origin and exhumation history of central East Antarctic igneous crust obtained from glacial erratics and by subglacial access drilling

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Covered by the East Antarctic ice sheet (EAIS), the crustal history of interior East Antarctica (EANT) is poorly known aside from that gleaned from geophysics, continental reconstructions and detrital mineral studies. A large suite of glacially-transported granitoid boulders collected from moraines near the heads of glaciers that drain central EANT through the Transantarctic Mountains (TAM) yield zircon U-Pb ages defining punctuated magmatic events at ~2.01, 1.88–1.85, ~1.79, ~1.57, 1.50–1.41, and 1.20–1.06 Ga. The discrete age populations have distinctive zircon $\delta^{18}O$ and initial ε_{Hf} isotopic compositions, varying from mantle-like, near-chondritic signatures at ~2.0 Ga; to mostly crustal compositions at ~1.88–1.85, ~1.79 and ~1.57 Ga; juvenile, mantle-like isotopic signatures at 1.50–1.41 Ga; and mixed crustal and mantle signatures at ~1.2 Ga. The dominant granitoid populations are ca. 1.85, 1.45 and 1.20–1.06 Ga. None of these ages are known in exposed Mesoarchean-Paleoproterozoic basement in the TAM (Nimrod Complex) or the Terre Adélie Craton, so this suite represents previously unrecognized Proterozoic crust hidden beneath the EAIS. Ross-age granitoids also populate the moraines and are present in the nearby TAM basement, but we selected Proterozoic glacial erratics for low-temperature thermochronology because they must have been eroded from an unexposed, inboard igneous province that can constrain the cooling/exhumation record of central East Antarctic crust. This crust may be imaged by subglacial aeromagnetic anomalies that extend from the central TAM across the adjacent EAIS such that the catchment for the glacial erratics may extend from the Byrd Glacier inlet to the southwestern Gamburtsev Subglacial Mountains. Apatite fission-track ages from selected clasts range from 80 to 480 Ma with complex track-length distributions, while mean apatite (U-Th)/He ages range from 65 to 385 Ma. Inverse thermal modeling constrains episodic rapid cooling at ~500, ~180, and ~90 Ma, grouped as follows by U-Pb age: Group 1 samples (~2.0-1.8 Ga) experienced rapid cooling during late Ross Orogen time, with some also cooling rapidly since the Cretaceous, but with no Jurassic signature; Group 2 samples (~1.5-1.2 Ga) experienced rapid cooling during the Jurassic, with some samples also cooling rapidly during the Cretaceous. None of the thermal models show evidence of partial resetting due to burial or igneous activity, although we cannot rule out that Group 2 samples had a Ross signature that was completely reset in the Jurassic. Taken together, previously unrecognized Proterozoic igneous crust in central EANT underwent rapid cooling associated with Ross Orogen and/or greater Pan-African tectonism, Ferrar Large Igneous Province magmatism, and Cretaceous exhumation, similar to the known TAM history. The onset of Cretaceous rapid cooling, dominantly at ~100-80 Ma, possibly occurred surprisingly deep in the cratonic interior and may be linked with early formation of the TAM, Antarctic-Australian separation, and/or initiation of the West Antarctic Rift System. Notably, no samples indicated Cenozoic cooling and exhumation associated with the dominant episodes of TAM uplift, further supporting a distal glacial source within central parts of the craton. Although their transport distance is not known, the crystallization and cooling ages provide important clues about the crustal, tectonic, and exhumation history of central EANT. If the clasts were derived from the western flank of the Gamburtsevs, it is

possible that this subglacial massif may be composed of Proterozoic igneous crust that has an early Paleozoic and Mesozoic cooling history related to known tectonic events affecting large segments of the continent. Given such uncertainties, the need for 'ground truth' in geological exploration of the EANT interior motivates development of a Rapid Access Ice Drill to quickly penetrate the ice sheet and obtain rock cores of high scientific value.

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South Georgia microcontinent: current tectonic setting from GPS and marine seismic data

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The South Georgia microcontinent (SGM) is an allochthonous block displaced from south-east Tierra del Fuego. It was transported over the past 80 -100 My as a result of transpressive deformation during the initial mid-Cretaceous phase of Andean orogenesis and subsequent development of the western part of part of the Scotia Plate (SCO). While its trajectory is poorly constrained, SGM is now located near the eastern extremity of the North Scotia Ridge (NSR), approximately 1600 km east of its original position. West of the SGM, the NSR forms the South America plate (SAM) - SCO boundary. Based on Scotia Arc bathymetric morphology and geological history, SGM has been considered part of the SCO, with the plate boundary along its northern side. SGM seismic activity, while very low, is concentrated along its southern border and interpreted, based on a few small thrust mechanisms, to represent underthrusting and uplift of South Georgia Island on a NSR restraining bend along the north-eastern margin of SGM. More recently, also based on this seismicity, the plate boundary has been placed on SGM's south side, suggesting SGM has, or is being, transferred to SAM. We report on marine seismic reflection surveys north and south of the island, and results from a 4 station continuous GPS network installed on the island, to determine the block's current tectonic affinity with respect to the SAM and SCO plates, to examine SGM for internal deformation, and to evaluate the significance of relative sea level change measured by a tide gauge on the island. We will present preliminary geodetic results, based on 4 years of continuous GPS data, indicating SGM motion and deformation. We will also present multi-channel seismic reflection profiles across the margins of SGM showing indications of compression. SGM appears to be moving as an independent microplate. The anomalously high relief of the island relative to the hinterland of the southernmost Andes (~3000m vs. ~1000m) may result from the impingement of the Northeast Georgia Rise on the microcontinent.

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Relative plate motion between East and West Antarctica since the Eocene: what we know and what we don’t

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Motions between East and West Antarctica are derived by geophysical constraints from the northern-edge of the West Antarctic rift system (WARS) and by data straddling the adjacent seafloor spreading systems. East - West Antarctic mid-Cenozoic pulse of motion resulted in an ultraslow seafloor spreading in the Adare and Northern Basins that lasted between 43 and 26 Ma (magnetic anomalies 20 to 9, Cande et al., 2000). The combination of magnetic anomaly data from these two basins (Damaske et al., 2007) together with geophysical constraints collected in the Southeast Indian Ridge (SEIR, Australia - East Antarctica to the west of the Balleny fracture zone and Australia - West Antarctica to the east) were used to set up an Australia - East Antarctica - West Antarctica three-plate solution (Granot et al., 2013). Recent magnetic observations collected across the eastern part of the SEIR (Granot and Dyment, 2018) showed that the motions between East and West Antarctica lasted until 11 Ma (anomaly 5o) after which Antarctica has unified into a single plate. Three-plate kinematic solution for this young Neogene motion was derived based on seismically controlled estimates of extension in the Terror Rift (Henry et al., 2007) and the SEIR geophysical data. This phase of motion records the last stage of lateral displacement within the WARS whereby a major change in the direction of East – West Antarctic relative plate motion was coupled with a decrease in plate velocity. The kinematic evolution of the rift has major implications for the distribution of volcanic activity, heat flow pattern and the development of topography within and near the rift system. In this presentation, I will discuss these issues and highlight WARS-related still open questions.

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Mantle viscosity structure and lithosphere thickness beneath Antarctica

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Upper mantle viscosity structure and lithospheric thickness control the solid earth response to variations in ice sheet loading. These parameters vary significantly across Antarctica, leading to strong differences in the timescale of glacial isostatic adjustment. We utilize two new seismic models for Antarctica to develop improved estimates of mantle viscosity and lithospheric thickness. Both seismic models take advantage of numerous temporary broadband seismic stations deployed across Antarctica over the past 18 years. Shen et al. [2018] use Rayleigh wave velocities from earthquakes and ambient noise, as well as receiver functions to develop a higher resolution model for the upper 200 km beneath Central and West Antarctica, where most of the seismic stations have been deployed. Lloyd et al [submitted] use a full-waveform adjoint method to invert complete three-component earthquake seismograms for a radially anisotropic model covering Antarctica as well as the adjacent oceanic regions to 800 km depth. We estimate the mantle viscosity structure from the seismic structure assuming laboratory-derived relationships between seismic velocity, temperature, and rheology. We also describe and compare several different methods of estimating lithospheric thickness. The results indicate several orders of magnitude variation in viscosity across Antarctica, with extremely low viscosity (< 1019 Pa s) beneath the Amundsen Sea coast and the Antarctic Peninsula, consistent with estimates from glacial isostatic adjustment models constrained by GPS data. Thin lithosphere and low viscosity between Thurston Island and the Antarctic Peninsula likely result from the effects of the slab window as the Phoenix-Antarctic plate boundary migrated northward during the Cenozoic. Low viscosity regions beneath the Amundsen Sea Embayment and Marie Byrd Land coast connect to an offshore anomaly at depths of ~ 250 km, suggesting the involvement of larger-scale thermal and geodynamic processes that are perhaps linked to the initial rifting of New Zealand and Antarctica in the Cretaceous.

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Late Triassic magmatism of Antarctic Peninsula and its implications for the Gondwanan margin of West Antarctica: a revised tectonic evolution

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West Antarctica is considered to be composed of an amalgamation of several continental blocks, including the Antarctic Peninsula, which were originally dispersed along the southern margin of Gondwana, and have affinities with South America, New Zealand and southern Africa. Prior to the Mesozoic disassembly of Gondwana, these blocks were located along the so-called Terra Australis margin, where proto-Pacific oceanic lithosphere was subducted beneath this pre-Mesozoic continental margin.

Rifting of South America, Africa, East Antarctica, India, Australia and New Zealand drove crustal block translations and rotations that subsequently led to the breakup of Gondwana and to the assembly of West Antarctica. Although there have been a series of recent improvements, there are still standing issues understanding the timing and geodynamic development of West Antarctica and the proto-Antarctic Peninsula during Paleozoic and early Mesozoic.

We present new geochronological (zircon U-Pb obtained using LA-ICP-MS; Laser Ablation – Inductively Coupled Mass Spectrometry), geochemical (whole rock) and isotopic (whole rock Nd, Sr, Pb; zircon Hf) data acquired from Triassic igneous units exposed in the Antarctic Peninsula (Graham and Palmer Land) and along the Central and Eastern domains of Vaughan and Storey (2000). Whole-rock geochemistry from a series of Late Triassic orthogneisses yielded high-K calc alkaline affinities with meta- and peraluminous compositions. The trace elements and Sr-Nd-Pb whole rock isotopes indicate a significant presence of subduction-derived components in their source, which suggests that the Late Triassic melts in both domains (Central and Eastern) were formed above an active subduction zone.

Zircon rims yielded Late Triassic concordant ages in the Central and Eastern domains, which constrain the timing of magmatism. Our data show a conspicuous presence of zircon xenocrystics cores with contrasting ages between both domains. While Paleozoic magmatic activity is recorded mostly in rocks from the Central Domain, a paucity of the Paleozoic magmatism is registered in the Eastern Domain.

We show that the paucity of Paleozoic magmatism in the xenocrystic zircons of the Eastern Domain might indicate that this domain was located in an interior position within Pangea, distal from the axis of the arc magmatism. In contrast, the abundant presence of Paleozoic xenocrystic zircons of the Central Domain probably reveals the presence of an active margin during this period along this geological sub-province, which we equate with Terra Australis Margin of South America. Further, Lu-Hf model ages of the Paleozoic zircon cores yielded ages that suggests that the basement of the Antarctic Peninsula probably consist of a Paleozoic arc re-melted from Sunsas-aged rocks (ca. 1.2 –

0.9 Ga).

We suggest that the sinistral transtension prevailing along south-west Gondwana during the Triassic was also present in the sector of the proto-Antarctic Peninsula. These dynamics juxtaposed the Central and Eastern domains within the Late Triassic arc. Further, while the Eastern Domain was displaced from a foreland position to the margin axis, the Central Domain drifted relatively to the south. The data implies that the Antarctic Peninsula was probably formed by transtensional movements along the margin and support an in-situ margin evolution from, at least, the Late Triassic.

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Geometry and Neogene evolution of Terror Rift, western Ross Sea, Antarctica

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Terror Rift developed in the broader Victoria Land Basin (VLB) adjacent to the Transantarctic Mountains, as a 400 km-long, 50-70 km-wide, up to 14 km-deep sedimentary basin. It belongs to the Mesozoic/Cenozoic West Antarctic Rift System (WARS) and continues farther south beneath the Ross Ice Shelf.

A post-29 Ma seismic stratigraphic and fault interpretation was developed, using all resolutions of seismic reflection data available, including the multichannel seismic reflection data (MCS) from the Seismic Data Library System, and by correlating seismic stratigraphy from the core holes in the McMurdo Sound area, and from the Deep Sea Drilling Program (DSDP) sites farther east.

Depth conversion using a new 3D velocity model was performed on gridded stratigraphic horizons and on MCS data crossing Terror Rift. Thirteen interpreted depth sections were used to measure two components of vertical motion from rift flanks to basin center. These components are vertical separation across faults, and stratal dip, usually the result of progressive tilting. Extension of Miocene horizons across faults was also calculated.

The Terror Rift model presents a different relief accommodation on the two flanks, showing tilting combined with faulting along the western side and an alternation in 4 segments between faulting and tilting on its eastern flank. Accommodation zones separate fault-controlled segment of the eastern margin from dip-controlled segments. An anticline (Lee Arch) on the eastern border of the TR is dissected by the N- striking up-to-the-basin and down-to-the-basin steep to sub-vertical faults which form a geometry similar to a negative flower structure. Some of the offshore faults have reverse separation of late Miocene and possibly younger strata, and parts of other faults are vertical, consistent with right-lateral slip and oblique rifting after ~26 Ma.

We consider tilting linked to differential subsidence since at least 29 Ma in southern Terror Rift, and vertical-separation of strata across faults in central and northern Terror Rift since at least 21 Ma until post-Miocene time, demonstrating tectonic activity after ~29 Ma and continuing after 21 Ma. Certain faults exhibit sea floor scarps or fault line scarps, with almost one km of vertical separation of a younger than 7.5 Ma horizon. We measure no significant change in rate of total subsidence of southern Terror Rift through late Oligocene and Miocene time. This differs from published papers that propose that significant tectonic extension did not occur between 23 and 13 Ma (e.g., Fielding et al., 2008).

Published plate tectonic studies indicate that extension slowed about 26 Ma, and 30 km of oblique extension-right-lateral displacement occurred across Terror Rift between 26 and 11 Ma (Granot and Dyment, 2018). We measure less than 4 km of extension of a 21 Ma unconformity across offshore mapped faults imaged on a MCS profile extension. This suggests that Terror Rift was a mostly transtensional dextral transform boundary between 26 and 11 Ma. Given evidence for post-7.5 Ma activity on faults, Terror Rift changed from an orthogonal rift before 26 Ma to a transtensional

transform boundary after 26 Ma, into or through post-Miocene time.

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Crustal and Uppermost Mantle Radial Anisotropy beneath Antarctica from Surface Wave Ambient Noise Tomography

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The distribution of amplitude and orientation of seismic anisotropy reveals the deformation history of the crust and mantle. Whereas most former studies of Antarctic seismic anisotropy focus on azimuthal anisotropy with either shear-wave splitting or relatively low-resolution structural models, the use of Rayleigh and Love wave phase and group velocities from ambient noise can provide better-resolved shear wave velocity structure as well as determinations of radial anisotropy, the difference between the speeds of vertically (VSV) and horizontally (VSH) polarized shear waves. In this study, we derive a model for crustal shear wave velocity in West Antarctica and central Antarctica, using both interstation Love and Rayleigh wave Green's functions estimated from the cross-correlation of ambient noise records. We use all available broadband data collected in Antarctica over the past 18 years, including data from recent temporary arrays such as TAMSEIS, AGAP, TAMNNET, RIS and POLENET/ANET. Group and phase velocity maps for both Rayleigh and Love waves are obtained and are then inverted for shear wave velocity structure using a Monte Carlo inversion method. Most of the major features of the VSH structure are consistent with the VSV structure derived by a previous study developed from Rayleigh wave inversion alone. Major geological features in Antarctica, such as the thick sediments in the Ross Embayment and the crustal root beneath the Gamburtsev Subglacial Mountains, are evident in the shear wave structure. However, some shallow structural details are resolved in the newer model that were not seen in the VSV structure, such as low velocities beneath the Polar Subglacial Basin and Byrd Subglacial Basin. Joint inversion of Love and Rayleigh wave data also allows us to determine the radial anisotropic structure of the crust and uppermost mantle. Most of the middle crust in West Antarctica has very weak positive anisotropy (VSH > VSV), indicating almost isotropic structure. The middle and lower crust beneath the Ellsworth-Whitmore Mountains shows strong positive anisotropy, likely due to horizontal fabric developed during the rotation of this terrain into its current location. The lower crust beneath the Byrd Basin and other basins in West Antarctica show negative (VSV > VSH) anisotropy. The crust beneath the Gamburtsev Subglacial Mountains shows positive radial anisotropy that increases with depth. The uppermost mantle of West Antarctica shows strong positive radial anisotropy (4 -5%), as is typical for normal upper mantle structure due to the lattice preferred orientation of olivine.

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Tectonic and magmatic evolution of a distributed plate boundary in the South Pole Frontier

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Recent continent-wide magnetic and gravity compilations and GOCE satellite gravity gradient data have shed significant new light into the lithospheric architecture and tectonic evolution of interior East Antarctica. However, despite these advancements the South Pole region itself has remained much less well-known, due to the paucity of modern aerogeophysical research in this frontier and the gap in GOCE observations around the South Pole.

Here we present results from the PolarGAP project of ESA that successfully filled the GOCE data void with new reconnaissance aerogeophysical observations, thereby helping unveil both the subglacial topography and the deeper crustal architecture of the South Pole frontier. By combining enhanced aerogravity and aeromagnetic imaging (that includes a compilation with pre-existing datasets) with potential field modelling and plate reconstructions, we interpret several major tectonic and magmatic events that affected the region, and discuss their broader linkages with plate tectonic evolution in particular for Jurassic and Cambrian times.

The new bedrock topography map derived from airborne radar images the Pensacola-Pole Basin, demonstrating that it stretches from the Jurassic Weddell Sea Rift System to South Pole, while the new free-air gravity data reveal a system of inferred en-echelon grabens within the basin itself. We interpret these basins as part of the Jurassic Transantartic Rift System, and identify several preserved subglacial parts of the Beacon Superbasin within the study region. We further propose that the Jurassic rift basins were superimposed upon a long-lived and originally more distributed (and mostly strike-slip) plate boundary between East and West Antarctica, which also included several distinct pre-existing microplates/terranes.

High-frequency magnetic anomaly patterns along individual profiles help delineate the remnants of the Jurassic Ferrar Large Igneous province preserved within these subglacial grabens, while longer wavelength magnetic anomalies reflect several distinct uplifted basement blocks. The long-wavelength anomalies reveal the stark contrast between the early Cambrian rift-related rocks emplaced in an inferred broad back-arc related embayment within the Paleo-Pacific margin of Gondwana and a composite Recovery Block identified further inland. We interpret the latter as a composite Precambrian microplate, which we image as extending from the eastern flank of the Pensacola-Pole Basin to the Shackleton Range, where several distinct Precambrian terranes are relatively well-exposed.

We conclude that the southern edge of this composite microplate, which is tectonically juxtaposed against the so called (and in part disputed) Queen Maud Terrane, exerted significant structural controls on both the back arc region of the early Paleozoic Paleo-Pacific active margin and on parts of the later intracontinental Jurassic rift system, which underlies the Pensacola-Pole Basin.

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Neoproterozoic geodynamic evolution of easternmost Kalahari: Constraints from new U-Pb-Hf-O zircon and Sm-Nd isotope data of basement rocks from the Schirmacher Oasis, East Antarctica

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Late Tonian (ca. 785–760 Ma) meta-igneous rocks of the Schirmacher Oasis region in Dronning Maud Land (DML), East Antarctica, are interpreted to record an active continental margin setting at the periphery of Kalahari and Rodinia. The investigated granodioritic to granitic rocks probably represent a significant tectonic province hidden underneath the ice, the erosional remnants of which are recorded as detrital zircons in Neoproterozoic metasedimentary rocks throughout central and eastern DML. The late Tonian meta-granitoids have Nd model ages of c. 1.3-1.5 Ga, indistinguishable from the adjacent Grenville-age basement rocks of easternmost Kalahari. Their respective zircon Hf-signatures are also similar. Their geochemistry suggests that they evolved in the late stage of a continental margin magmatic arc and possibly within a roll-back tectonic framework.

The rocks show ultra-high temperature metamorphic overprint that was accompanied by syn-tectonic magmatism from ca. 650 to 600 Ma. The ultra-high temperature metamorphism is interpreted to relate to back-arc extension that also led to major anorthosite magmatism in the region. The rocks lack subsequent high-grade metamorphic overprint from 590-500 Ma, as has been recorded in the adjacent regions due to Himalayan-style continental collision along the East African-Antarctic Orogen. Within Gondwana, these rocks may correlate with the Cabo Delgado nappe complex in northern Mozambique, there are also similarities to the Eastern Granulites in Tanzania.

The tectonic setting of the eastern Kalahari margin in late Mesoproterozoic to Neoproterozoic times had remained unclear so far, due to its prolonged high-grade tectono-thermal reworking as a result of Gondwana assembly. Our new results reveal that the collision of Kalahari with Laurentia heralds the beginning of long-lived, periodic convergence along the eastern Kalahari margin between ca. 1050 and 700 Ma, recording the final stages of Rodinia assembly, Rodinia break-up and the subsequent assembly of Gondwana.

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Proterozoic evolution of central Dronning Maud Land (East Antarctica) from Rodinia to Gondwana

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Central Dronning Maud Land (CDML) in East Antarctica is an important region for understanding Rodinia and Gondwana supercontinent cycles. Zircon U-Pb dating and Hf-O isotopic data revealed by extensive sampling across CDML provide constraints on the timing and source of main magmatism and new insights into the crustal composition and evolution. SIMS zircon U-Pb ages indicate multi-stage magmatic activities from Mesoproterozoic to Cambrian times at 1160-1130 Ma, 1115-1100 Ma, 1090-1070 Ma, 780-750 Ma, 645-600 Ma and 530-485 Ma, as well as Mesoproterozoic metamorphism at 1085-1050 Ma recorded by zircon rims. This region was subjected a large-scale and long-lasting high-grade metamorphism during 600-500 Ma.

Most 1150-1090 Ma granitic rocks exhibit εHf (t) values ranging from +5 and +8 and δ18O slightly higher than mantle value (6-7 ‰), indicating a main derivation from juvenile crust. The involvement of Paleoproterozoic continental materials, which were most likely from adjacent Kalahari Craton, is attested by minor samples with negative to neutral εHf (t) and significantly elevated δ18O values (8-10 ‰). The late Neoproterozoic (750-600 Ma) rocks, including anorthosite, charnockite and granite, display an evolved Hf isotopic composition and high δ18O values (7.5-9 ‰), suggesting a significant addition of crust-derived materials into the source.

The data imply that in CDML, late Mesoproterozoic (Grenville-age) magmatism during the assembly of Rodinia is dominated by the addition of new crust with subordinate reworking of ancient crust. Subsequent subduction process associated with the break-up of Rodinia and assembly of Gondwana largely witnessed recycling of previous continental components. Combined with whole-rock geochemistry, it is speculated that the accretionary process along the Maud margin of Kalahari Craton lasted from the Mesoproterozoic, across the late Tonian (750 Ma) until Ediacaran to suture west and east Gondwana blocks.

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Lithospheric magnetic anomaly modelling from Antarctic near-surface and satellite observations

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The second-generation Antarctic magnetic anomaly compilation grid, ADMAP-2, was combined with Swarm satellite magnetic observations into a localized magnetic anomaly model of spherical Slepian basis functions. The degree n = 1800 (wavelength resolution ~ 45 km) spherical harmonic model valid only for the Antarctic region south of 60 degree south of latitude incorporated by joint inversion the longer wavelength components (n ≤ 185) from the ADMAP-2 and satellite observation. The higher wavelength components from ADMAP-2 that are marginally present at the satellite altitude (~ 250 km) were then added to the long wavelength components to obtain the final set of Slepian coefficients. The resultant Slepian model accommodates these data components at near-surface and satellite altitudes to provide unique insights into the altitude behavior of the lithospheric magnetic anomalies, which are not available from simple continuations of the individual ADMAP-2 and Swarm datasets. In addition, the Slepian coefficients can directly update the spherical harmonic coefficients of the World Digital Magnetic Anomaly Map (WDMAM) to improve the world map's Antarctic magnetic anomaly estimates.

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Achievements and aspirations of AWI airborne geophysics in Antarctica

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Aerogeophysics at the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI), has entered its 25th year. Over that time, a variety of stand-alone and collaborative projects have been completed with a range of German, European and international partners. Early fixed-wing configurations in Dornier aircraft comprised radio-echo sounding and magnetic systems. A gravimeter was added in 1998. Dornier aircraft were replaced by Baslers starting in 2007. Helicopter-magnetic acquisition has been undertaken using RV *Polarstern* as a marine base since 2000. Data have been acquired in both east and west Antarctica as well as offshore in the Pacific Ocean and Scotia Sea. Here I will concentrate on the Dronning Maud Land (DML) sector of East Antarctica.

The 1994/99 period saw a focus on establishing the regional structure of the ice sheet in western and central DML as part of the European Project for Ice Coring in Antarctica. This coverage was extended eastwards in 2001/05 as part of the VISA (Validation, densification and Interpretation of Satellite data for the determination of magnetic field gravity field ice mass balance and structure of the earth crust in Antarctica using airborne and terrestrial measurements) project, since 2008 as part of the ongoing GEA (Geodynamic Evolution of east Antarctica) project in collaboration with the German Federal Institute for Geosciences and Natural Resources (BGR), in 2006 in collaboration with Japan's National Institute for Polar Research (NIPR), and in 2013/14 and 2015/16 as part of AWI glaciological surveys in the Recovery Lakes and Dome F regions. The current interpretation of the onshore geological evolution of DML from these data is underpinned by targeted geological sampling from moraines and nunataks during VISA and GEA. It envisages Gondwana amalgamation by collisions of multiple volcanic island arcs between converging cratonic parts of today's Africa and East Antarctica. Ongoing work aims to use densified coverage in western DML to understand the source of the Forster Magnetic Anomaly, a prominent feature of the collision zone. Offshore DML, the solid-Earth focused EMAGE project (East Antarctic Margin Aeromagnetic and Gravity Experiment) in 1995-2002 used a combination of fixed-wing flights from onshore strips and offshore helicopter surveying. The post-2006 period saw the addition of offshore data in the Riiser-Larsen and Cosmonauts seas and in the western and central Enderby and Falkland Plateau basins. The results are interpreted in terms of processes of Gondwana breakup and the subsequent history of seafloor spreading.

Future plans include expanding GEA's coverage eastwards and southwards of DML in collaboration with BGR and the NIPR, maintaining 10 km flight spacing. Geological issues that aim to be addressed with these data include locating the southern extent and of TOAST, and its relationship to features such as the Gamburtsev suture and East Antarctic Rift System. Further survey ideas that are in discussion and at proposal stage focus on onshore and offshore targets in both east and west Antarctica. Upcoming changes in the scientific usage classification of Polar 5 and Polar 6 are intended to broaden the range of users and targets further still, opening up opportunities for new partnerships and project ideas.

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Session02: Structure, evolution, and heterogeneity of Antarctica's continental lithosphere

Radially Anisotropic Seismic Structure of the Antarctic Upper Mantle Based on Full Waveform Adjoint Tomography

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The seismic structure of the Antarctic upper mantle and transition zone has been amongst the poorest imaged regions of the Earth's interior. To remedy this situation, we developed ANT-20 (Lloyd et al., submitted 2019), a new seismic structural model based on full-waveform adjoint tomographic techniques. This new model utilizes phases observations from three-component earthquake seismograms containing both body and surface waves from 270 earthquakes recorded at 323 seismic stations over the last 18 years. High resolution images of the shear wave speed structure possess sufficient resolution to connect tomographic features to dynamical advection of thermal and chemical heterogeneities beneath the entire continent as well as the surrounding oceans. Although many new and intriguing features are revealed in ANT-20, we focus on two unique slow shear wave speed anomalies that suggest a connection between geodynamical processes beneath West Antarctica and those underlying the Southern Ocean. The first anomaly follows the Transantarctic Mountain Front, bending to the west towards the Balleny Islands and continuing north to the Macquarie Triple Junction. Within this feature local minimums (less than -3%) exists beneath the southern Transantarctic Mountains, the Ross Island Region, and extending northward from the Hallett Volcanic Province. The slow shear wave speeds are confined to the upper mantle with anomalies less than -3% extending no deeper than 200 km. The second slow shear wave speed anomaly underlies the oceanic lithosphere of the Amundsen Sea stretching from ~90 degrees W to ~150 degrees W. As this anomaly ventures inland it shallows and connects to the slow shear wave speed structures beneath Marie Byrd Land and Thurston Island. The Amundsen Sea anomaly is characteristically distinct from the first, as it broader and more deeply root extending into the transition zone (between ~120 degrees W to ~160 degrees W) and possibly deeper. Finally, we will present an update on our ongoing work to develop an improved second generation full-waveform model incorporating double difference techniques and Greens Functions from ambient seismic noise correlation.

Session02: Structure, evolution, and heterogeneity of Antarctica's continental lithosphere

Spatial variations in effective elastic thickness reveal the subglacial lithospheric structure of Antarctica

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Antarctica contains almost ten per cent of Earth's continental crust, but this is mostly concealed by ice making it difficult to constrain its age, composition or structure. This is particularly true for East Antarctica, assumed on the basis of sparse coastal outcrop and transported detritus to comprise Archean and Paleoproterozoic cratons juxtaposed along Proterozoic and Cambrian orogenic belts of unknown geometry. These geologic arguments for a composite East Antarctica were long thought to conflict with seismic evidence for uniformly thick lithosphere suggestive of a single craton, but recent higher-resolution results show significant seismic velocity variations in the uppermost mantle lithosphere. This poor knowledge of subglacial geology also hinders interpretation of East Antarctic topography, which includes enigmatic subglacial mountain ranges attributed either to very slow erosion of Cambrian orogenic belts, Carboniferous shortening driven by far-field tectonic forces, or Permian and Cretaceous uplift along the flanks of a rift system. Here we present a map of effective elastic thickness (Te) for the Antarctic region, computed from the coherence between satellite Bouguer gravity data and rock-equivalent topography using a fan wavelet technique, with layers of ice and water condensed to rock layers using standard densities. This proxy for lithospheric strength varies with lithology and temperature and has been used in other continents to produce a map that distinguishes lithospheric domains of different tectonic setting and history. As found in another recent study of Antarctica that employed a similar technique, our map reveals heterogeneous Te values in East Antarctica, with a broad region of high Te in Wilkes Land interpreted as a craton. However, the higher spatial resolution of our map reveals more detail elsewhere, including an extension of the Wilkes Land craton towards the South Pole and Recovery Lakes regions, and a meandering corridor of low Te that separates the Wilkes–South-Pole–Recovery craton from other regions of higher Te. including the Grunehogna and Ruker cratons. This low-Te belt connects coastal outcrops that record Cambrian deformation and metamorphism, and follows a number of prominent upper crustal structures identified from aeromagnetic data that are likely to be no younger than ca. 500 Ma, based on the minimum age of detrital minerals at the continental margins. This low-Te belt also coincides with the location of the Gamburtsev Subglacial Mountains and Dronning Maud Land Mountains, confirming a spatial link between modern topographic relief and Cambrian orogenesis. We cannot rule out the possibility that present-day elevation reflects younger reactivation of these Cambrian structures, but the observed correspondence of high relief with low Te (and therefore relatively low flexural rigidity) does challenge suggestions that these mountains formed in response to flexural uplift at a rift shoulder.

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Assembly and breakup of Indo-Antarctica revealed

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Princess Elizabeth Land (PEL) has been the least surveyed continental sector on Earth and thus represents a critical gap in our understanding of the assembly and breakup of the Gondwana Supercontinent. We present new geophysical data from the first systematic survey of PEL that provide constraints on the geological history of East Antarctica and its ancient neighbors. New data from the interior of PEL reveal the inland extent of the suture between India, Australia, and East Antarctica, resolving a debate over the extent of Indian affinity lithosphere in Antarctica. New coastal ice thickness data reveal a lowland connecting farther into PEL than previously known that contains enough ice to raise eustatic sea level by approximately one meter. We show that this coastal basin lies atop lithosphere that thinned during continental breakup, resulting in low topography along the coasts of PEL and the conjugate area in India's Bengal Basin. The results indicate how ancient geological processes have resulted in an ice sheet susceptible to climate-paced marine ice sheet instability and an Indian coastline naturally susceptible to seawater inundation.

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A tectonic control on the timing, chemistry and scale of voluminous pulsed intrusive magmatism: Evidence from the Lassiter Coast, Antarctic Peninsula

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Whilst magmatic flare-ups (and consequently Phanerozoic continental growth) commonly coincide with periods of tectonic deformation, their direct association is ambiguous. We present the evolution of a ~13,000 km2 intrusive suite in Antarctica and show how its pulsed emplacement, chemistry and volume were controlled by syn-magmatic deformation, by combining magnetic anisotropy (AMS) data with field, structural, geochemical, and geochronological evidence.

The Lassiter Coast Intrusive Suite (LCIS) of the Antarctic Peninsula provides a unique opportunity to observe the evolution of a pulsed syn-tectonic intrusive suite. The LCIS is one of the largest magmatic events in West Antarctica, and its timing and scale during the Mid-Cretaceous period of global deformation and extensive trans-Pacific magmatism renders it of both regional and global significance.

New U-Pb zircon ages show that this voluminous intrusive suite was emplaced in three pulses (118, 113 and 110 Ma) followed by 15 Ma of waning plutonism. AMS, field and geobarometric data allow the syn-magmatic (rather than pre- or post- magmatic) deformation to be determined. This shows that the magmatic pulses are coincident with peaks in syn-magmatic deformation bracketed by post-compressional extension, whilst the waning magmatism is post-orogenic. Zircon oxygen and hafnium isotopic data reveal the effect of the variable deformation on the generation and evolution of magma, whilst also revealing new details on the nature of the Gondwanan margin's crustal structure and the origin of the regional low δ18O magmatism.

This data highlights the causal link between voluminous pulsed magmatism and crustal deformation, with the pulsed timing of magmatic flare-ups deriving from pulses in tectonic compression; a result of deformation increasing melting and aiding ascent.

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Heterogeneous crustal motions across West Antarctica

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The rich and extensive datasets collected by the Antarctic Polar Earth Observing Network (POLENET-ANET) GPS and seismological arrays have produced new insights into the geological and geophysical structure of the Antarctic continent and how ice sheet behavior is linked with the structure and evolution of the underlying solid Earth. The geodetic component of ANET provides high-precision bedrock crustal velocities in response to the changing mass of the Antarctic ice sheet. Observed crustal displacements show complex patterns and vary strongly both within and between different regions of the Antarctic continent.

Sustained uplift rates of 15 - 50 mm/yr occur in the Amundsen Embayment region, some of the fastest rates ever recorded for glacial isostatic adjustment (GIA). Over a relatively short spatial scale, motions in the Amundsen region change to downward displacements, interpreted as a collapsing forebulge around an uplift dome. GIA modeling indicates a very low mantle viscosity, consistent with seismic observations in this region (Barletta et al., 2018). Low mantle viscosity shortens the GIA response time scale from thousands of years, to hundreds or even tens of years. The weak Earth structure under the marine ice sheet and the very fast uplift rates set up a rapid stability feedback that can impact the evolution of the West Antarctic Ice Sheet at the centennial time scale.
At the millennial time scale, the presence of low viscosity under West Antarctica is important for developing improved paleo- ice sheet reconstructions and assessing potential WAIS collapse scenarios.

Measured uplift rates are substantially lower than predicted by GIA models in the Weddell and Marie Byrd Land regions and much higher in the Amundsen Embayment and southern Transantarctic Mountains (TAM) regions. These mismatches demonstrate that either the radial viscosity profiles and/or the deglaciation histories used by the models are incorrect, and (given their coupling) most likely both. In some regions, gradients in measured vertical displacement rates coincide spatially with lateral variations in seismic velocities and, by inference, with changing earth properties such as lithosphere thickness and upper mantle viscosity. Horizontal displacement patterns also show spatial relationships with strong gradients in earth properties. Integrating results from crustal motion patterns derived from GPS with seismic mapping of earth structure is essential for developing a new generation of 3-D GIA models.

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Locating the East-West Antarctica boundary beneath the Ross Ice Shelf

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Bedrock topography beneath the Antarctic ice sheets reflects the broad contrast between the old, thick Antarctic craton, supporting high topography and the younger, thinner crust of West Antarctica, which has been further thinned by the Cenozoic development of the West Antarctic rift, reaching depths of nearly 3 km below sea level. The exact location of the boundary between East and West Antarctica has proved difficult to identify due to limited exposure of rock around the continent.

New aerogeophysical data from the ROSETTA-Ice project over the Ross ice Shelf reveal a striking contrast in the magnetic character on either side of a distinct boundary that bisects the ice shelf from north to south. This boundary can be traced in regional magnetic datasets across the Ross Sea continental shelf and is here interpreted to mark the boundary between East and West Antarctica. Werner deconvolution of the magnetic anomalies reveals that the boundary lies within the continuation under the Ross Ice Shelf of the basement Central High, observed in the Ross Sea from seismic surveys. Bouguer gravity anomalies across the ice shelf show higher values on the East Antarctic side of the Ross Ice Shelf, representing thinner crust between the Central High and the Transantarctic Mountains.

The identification of this boundary, 300 km to the east of the Transantarctic Mountain front, requires a revision of our understanding of the tectonic frame work of Antarctica and suggests heterogeneities in glacial boundary conditions that have persisted throughout the history of Antarctic glaciation.

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P-WAVE VELOCITY STRUCTURE BENEATH THE NORTHERN VICTORIA LAND: THE POSSIBLE HEAT SOUCE OF THE VOLCANOS

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The Extreme Geophysics Group (EGG) at the Korea Polar Research Institute (KOPRI) have installed a broadband seismic network called Korea Polar Seismic Network (KPSN) around Mt. Melbourne since 2011. The KPSN, currently, spreads from the Mt. Melbourne to the upstream of the David Glacier with 17 broadband seismic stations and one infrasound network at the Jang Bogo station.
The division of Polar Earth-system Science focused on the research named "Characterizing mantle domain beneath West Antarctic Rift System and Antarctic mid-ocean ridges", and install OBSs (Ocean Bottom Seismographs) in the sea near the Jang Bogo station to extend the observing coverage of the KPSN.
The P-wave upper mantle velocity structure was modeled using the teleseismic events observed on the KPSN and the Transantarctic Mountains Northern Network (TAMNNET) to extend the spatial coverage to the model. Our model shows two separate low-velocity anomalies at ~150km depth located beneath the Terra Rift and inland area of the Mt. Melbourne, respectively, but the tow anomalies connected below the ~150km depth and extend to ~300km depths. The ~300km depth extent of the low-velocity anomaly indicates the Terra Rift might be not an active rifting system.

A063

Session04: Antarctic Volcanism and Magmatism: Past, Present and Future

The Polar Rock Repository: a Scientific Resource for the Volcanology Community

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The Polar Rock Repository (PRR) is a NSF funded facility at the Ohio State University created to preserve and provide scientific access to rock, terrestrial drill core, unconsolidated till/soil and marine dredge sample collections from Antarctica and the southern oceans. Currently more than 50,000 samples are available as no-cost loans for research. Scientists may request samples from the PRR website and conduct research using destructive techniques. In addition to the physical samples, the PRR archives supporting materials from the collector, such as images of the samples, field maps, air photos, thin sections and any associated bibliography/DOI's. Graduate and undergraduate students routinely use samples from the PRR for their research projects.

The PRR contains more than 4000 Cenozoic igneous rocks from Antarctica, as well as volcanic samples from southern oceans dredges. The samples come from almost all Cenozoic volcanic locations on the continent. A unique collection includes the Erebus volcanic province DVDP Ross Island drill cores 1, 2 and 3 that were cored to a depth of 380 m. Another unique collection includes Deception Island samples collected from specific eruption events. Samples from remote locations in West Antarctica are also available for research.

Researchers can search for samples using the PRR website. An advanced search engine for the PRR website allows scientists to "drill down" into search results using categories and look-up object fields similar to websites like Amazon. Results can be viewed in a table, downloaded as a spreadsheet, or plotted on an interactive map that supports display of satellite imagery and bathymetry layers. Samples can be requested by placing them in the 'shopping cart'. The easy discoverability of the PRR samples using the online search and shopping tools helps scientists with research planning, particularly given how logistically difficult, financially expensive and the high environmental impact of conducting Antarctic field research.

A064

Session04: Antarctic Volcanism and Magmatism: Past, Present and Future

Magma Storage and Ascent Beneath the Erebus Volcanic Province, Antarctica: Insights from Olivine-Hosted Melt Inclusions

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Depths at which magmas are stored, their pre-eruptive volatile contents, how they degas, and their ascent rates are interrelated, and exert important controls on the dynamics of volcanic eruptions. Magmas stored in deeper reservoirs experience less pre-eruptive degassing and are, therefore, richer in volatiles. Closed-system degassing increases the potential for explosive eruptions, and the rate at which magma ascends influences the efficiency of vapor bubble nucleation, growth, and coalescence. Olivine-hosted melt inclusions (MIs) from the Erebus volcanic province of Antarctica provide an opportunity to investigate some of these interrelationships for a large alkaline province. Most eruptive activity occurs in the Ross Island and Discovery sub-provinces, each comprised of a central stratovolcano (Mt Erebus and Mt Discovery, respectively) surrounded by three radially distributed eruptive complexes. Tephras were collected from peripheral volcanic centers in each sub-province and supplemented with hyaloclastite from Core 3 of the Dry Valley Drilling Project (DVDP3). Olivine grains containing glassy MIs were separated out from these basanites for study. The inclusions preserve information relating to magma storage and ascent beneath these volcanos. The concentrations of H2O and CO2 are used to determine the depths of entrapment through comparison with a solubility model [1]. However, all inclusions contain vapor bubbles (VBs) that must also be accounted for when determining the total entrapped CO2 [2]. The included glass was analyzed for volatiles by secondary ion mass spectrometry. We determined the density of CO2 within each VB using Raman spectroscopy and the volumes of MIs and VBs with X-ray microtomography. Total CO2 was derived by summing the included glass and the VB. Inclusions from Hut Point Peninsula on Ross Island have maxium H2O and CO2 contents of 2.12 and 1.36 wt%, respectively. These concentrations indicate a magma reservoir at a depth of ~24 km – in agreement with the seismically determined Moho beneath Ross Island [3]. Magma degassing during ascent drives diffusive loss of H2O from melt inclusions.The δD of the inclusions range from -68 to -8 ‰ and define a negative correlation with H2O concentration, which can be attributed to preferential loss of hydrogen (H) relative to the more slowly diffusing deuterium (D). The extent of diffusive H2O loss and D/H fractionation reflect ascent time and the nature of degassing (open versus closed system). Results from diffusion modeling are consistent with closed system degassing and an average ascent rate of ~0.5 – 2.0 m/s. This gives a transit time from the Moho of only ~3-13 hours. Inclusions collected from Hurricane Ridge on Mt Morning in the Discovery sub-province have maximum H2O and CO2 contents of 1.84 and 1.45 wt%, respectively. This is much higher H2O than had been previously inferred [4], and demonstrates that basanites throughout this region have similar volatile contents regardless of the presence or absence of kaersutite.

[1] Ghiorso and Gualda (2015) Cont Miner Pet 169; [2] Moore et al. (2015) Am Min 100, 86-823; [3] Finotello et al. (2011) Geophys J Int 185, 85-92; [4] Martin et al. (2013) Geochim Cosmochim Acta 122, 127-152.

A066

Session04: Antarctic Volcanism and Magmatism: Past, Present and Future

Imaging structural controls on the Erebus volcano magmatic system, Antarctica using the magnetotelluric method

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The active Erebus volcano, on Ross Island, Antarctica, offers a unique opportunity to understand the magmatic system of an alkaline volcano. Furthermore, Ross Island is situated in the Terror Rift within the West Antarctica Rift System and the relationship of Erebus to the rift environment is poorly known. Erebus has the world's only persistent phonolite lava lake in its summit crater, and thus provides a unique window into the heart of a degassing volcano's magmatic system. We used magnetotelluric (MT) techniques, developed by our team for use in Antarctica, to image the magmatic system underlying Erebus and the older volcanoes forming Ross Island. In addition, we are examining the mantle source of the magma and the role that the Terror Rift crustal structure plays in the active volcanism. Traditional petrologic models suggest that the Erebus phonolite forms by fractional crystallisation of a parental mantle-derived basanite magma probably in a series of stacked crustal magma chambers. Data were collected over three austral summer field seasons from 2014-2017. Measurements were made at 129 locations on Ross Island and vicinity. Up to 11 Phoenix Geophysics V5 systems coupled with Numeric Resources LLC high impedance preamplifiers were used. 3D inverse modelling completed using the HexMT finite element algorithm shows that we can resolve the crustal residence zones and the path taken by the magma as it ascends from mantle depths to the surface. Modelling results of the MT data show a sub-vertical ascent path from mantle depths with a significant lateral step occurring in the lower crust. MT models do not identify a series of vertically nested chambers predicted by the petrological work, rather a potential 'fault valve' system controlling ascent into the crustal system. Our work provides new insight into the nature of the magmatic system and origin of the phonolite magma that has implications for understanding the magmatic process occurring in rift systems globally, while providing the opportunity to compare the processes associated with volcanism in both compressional and extensional tectonic settings.

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Session04: Antarctic Volcanism and Magmatism: Past, Present and Future

Ferrar magma distribution: line source or restricted source and long distance transport?

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The apparent linear outcrop pattern of the Ferrar Large Igneous Province raises questions about how magmas generated in the mantle were distributed over a distance of 4000 km from the Theron Mountains in the Weddell Sea sector to southeastern Australasia. Ferrar rocks consist of hypabyssal intrusions, a layered basic intrusion, lavas, and phreatomagmatic deposits. They range from basalt to andesite in composition. The most primitive Ferrar rocks are olivine-bearing dolerite sills, which exhibit the characteristic isotope enrichment, high field strength element depletions and crustal trace element patterns, and anchor the compositional trends. Ferrar magmas are divided into the MFCT, which forms 99% of the province and has a coherent range of chemistry (SiO2 = 52-59%; MgO = 9.2-2.6%; Zr = 60-175 ppm; Sri = 0.7081-0.7138, εNd = −3.8 to −6.0), whereas the remaining 1% belongs to the SPCT which has a restricted and evolved composition (SiO2 = ~58%; MgO = ~2.3%; Zr = ~230 ppm; Sri = 0.7090-0.7097; εNd = −4.1 to −4.4). The SPCT occurs for 3500 km from the Theron Mountains to north Victoria Land. The MFCT sills show no geographic compositional variation or pattern, whereas the MFCT lavas exhibit compositional differences between principal outcrop areas. One model suggests multiple sites of magma generation in the mantle and vertical magma rise, principally into supra-crustal strata and to the surface. In order to yield the coherent MFCT chemistry, this implies similar processes in a heterogeneous mantle and similar crustal evolution, notwithstanding magmas also traversing lithospheric provinces with different ages and compositions. Further, the SPCT implies similar evolutionary processes at multiple sites in the crust to yield the highly evolved but geochemically distinct composition. The lack of magma diversity is at odds with multiple sites of generation. The highly restricted SPCT composition implies a single magma batch, which argues for the assertion that it was dispersed at mid to lower crustal depths from the proto-Weddell Sea region to north Victoria Land. The coherence of the MFCT also implies a common source region similarly located. This is the preferred model.

A099

Session04: Antarctic Volcanism and Magmatism: Past, Present and Future

Emplacement history of the volcanic sequence at Site U1513, Naturaliste Plateau and Mentelle Basin, IODP Expedition 369

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Recently published works and interpretation of available seismic sections across the Mentelle Basin and Naturaliste Plateau (NP) in the Indian Ocean indicate that extensive volcanism accompanied Early Cretaceous rifting between Australia-Antarctica and Greater India during the breakup of East Gondwana. However, no direct stratigraphic evidence for this was available until International Ocean Discovery Program (IODP) Expedition 369 drilled into the volcanic sequence for the first time at Site U1513 on the eastern NP. The volcanic sequence consists of interlayered tholeiitic flows and volcaniclastic breccias, cut by multiple intrusions. Baked and depositional contacts between flows and breccias suggest that at least five phases of eruption took place, possibly in response to episodic rifting events. Petrological and textural evidence suggest subaerial to shallow water eruption.

Shipboard geochemical data, verified by shore-based XRF analysis, are used to infer the relationship of Site U1513 volcanic sequence to other reported magmatic activities nearby, especially on southern and northern NP and southwest Australia. These data suggest geochemical affinity among Site U1513, dredged NP basalts, and Bunbury Basalt flows in southwest Australia. Petrogenetic modeling of major element data for the most primitive basalts (high MgO, Ni, and Cr) from Site U1513 yielded primary magma compositions indicating generation from a more fertile than normal ocean ridge mantle source. The similarity of major and trace element data for Bunbury Basalt samples and dredged NP basalts with those of Site U1513 flows and intrusives suggests that they can also be derived by crystal fractionation from Site U1513-like primary magma. Paleomagnetic evidence from the overlying volcaniclastic succession and within the volcanic sequence, combined with radiometric ages of dredged NP basalts support emplacement between ~130-136 Ma. The eruption of the oldest flows at Site U1513 is contemporaneous with the oldest Bunbury Basalt flows and the reported age of the earliest seafloor magnetic anomalies in the Perth Abyssal Plain. These results provide a direct link with the initiation of rifting between Australia-Antarctica and Greater India.

A107

Session04: Antarctic Volcanism and Magmatism: Past, Present and Future

Marine tephra record of a Holocene caldera-forming eruption of Mt. Rittmann, Antarctica: volcanological reconstruction and perspectives for its use as tephrostratigraphic marker in the Ross Sea.

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The near-source exposure of eruption deposits at Antarctic volcanoes is often limited owing to glacial processes making volcanological reconstructions challenging. Fortunately, ash fall from explosive eruptions are preserved in the offshore sedimentary record. Consequently, marine tephrostratigraphy offers a critical resource of data for volcanological reconstructions including age and recurrence of eruptions, intensity/magnitude and eruptive dynamics, and for the assessment of the potential volcanic hazards posed by ash-forming eruption at high southern latitudes volcanoes.
We report here the first results from PNRA - TRACERS project (TephRochronology and mArker events for the CorrElation of natural archives in the Ross Sea, Antarctica). These tephrochronological and tephrostratigraphical results are from five sediment cores recovered from the Wood Bay area in the Ross Sea, Antarctica. In all the studied cores we discovered a spectacular, stratified primary tephra of considerable thickness (up to 80 cm). According to the tephra characteristics, the eruption dynamics were initially dominated by hydromagmatic magma fragmentation conditions producing a prolonged, sustained, relatively wet and ash-rich eruptive column. The eruption then evolved into a highly-energetic, relatively dry magmatic eruption. The final phase of the eruption was then characterized by renewed efficient magma-water interaction and/or collapse of the eruptive column producing pyroclastic density currents and associated co-ignimbritic plumes. On the basis of the major and trace element geochemistry and the mineral assemblage of the tephra, Mt. Rittmann was identified as the tephra source and a Holocene age was determined by 14C and Ar/Ar methods. This tephra is an excellent tephrostratigraphic marker for the Wood Bay area in the Ross Sea and will be crucial for future synchronization of marine archives of this area.

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The role of volcanism in the making of Antarctica

John Smellie †

Antarctica has a diversity of volcanism unrivalled amongst the southern continents and it reflects the changing plate tectonic regimes that have influenced the continent over time. The volcanism varied from subduction-related to intra-plate and it ranges in scale from small monogenetic vents associated with post-subduction slab-window formation to voluminous intrusive, effusive and explosive volcanism of a Large Igneous Province associated with break-up of the Gondwana supercontinent. The volcanism has thus had a profound influence on the progressive construction of the continent over geological time (hundreds of millions of years). Antarctica also contains several volcanoes that are active or potentially active today, an aspect that is often overlooked. Some may be capable of altering climate, or at least weather patterns in the Southern Hemisphere. Volcanic sequences are also amongst the best means of documenting past environmental variations (and therefore climate, by proxy), particularly through Cenozoic global cooling. The volcanism has also probably been responsible for influencing the development of Life on Earth, by triggering one or more significant mass extinctions but, conversely, it may have enabled terrestrial life on the continent to survive multiple glaciations by providing volcanic refugia.

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Glaciovolcanic studies 300 km from South Pole: evidence for a highly dynamic Early Miocene East Antarctic Ice Sheet

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Volcanic studies are potentially a major source of palaeoenvironmental information yet they have only rarely been applied to environmental issues, especially the characterisation of past ice sheets. This talk is one of two presented at this meeting focused on a combined volcanological/palaeoenvironmental—petrological investigation of the two southernmost exposed volcanoes in the world. The volcanoes are situated far inland, at high elevation and just 300 km from South Pole. Evidence gleaned from the two volcanic outcrops suggests that the early Miocene (c. 20 Ma) East Antarctic palaeoenvironment was extremely dynamic. In particular, it fluctuated from comprising a significantly thicker-than-modern glacial cover that would have largely drowned the local summits (> 2900 m asl) of the Transantarctic Mountains, to ice potentially being completely absent, despite the similarity in ages of the two volcanoes. The results are a powerful illustration of how investigations of volcanic rocks can reveal important information on terrestrial palaeoenvironmental conditions in Antarctica that are otherwise unobtainable.

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Origin and evolution of basalt from Earth's southernmost volcanoes

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We present geochemical and isotopic constraints on the petrogenesis of two monogenetic, Early Miocene volcanoes, Mt. Early and Sheridan Bluff, which are the above ice expressions of Earth's southernmost volcanic field located at ~87°S on the East Antarctic craton. They are compared to alkaline basalts from the West Antarctic rift system in order to test affiliation and resolve mantle sources and cause of melting beneath East Antarctica. Basaltic lavas and dikes are olivine-phyric and comprise alkaline (hawaiite and mugearite) and subalkaline (tholeiite) types. Trace element abundances and ratios (e.g., La/Yb, Nb/Y, Zr/Y) of alkaline compositions resemble those from the West Antarctic rift and ocean island basalt (OIB), while tholeiites are relatively depleted and approach the concentrations levels of enriched mid-ocean ridge basalt (E-MORB). Whole rock Sr, Nd and Pb isotope ratios trend from a mixture of depleted MORB mantle (DMM) and high U/Pb mantle (HIMU) towards enriched mantle (EM II) and an EMII-like source is also suggested by mildly elevated delta18O in olivine (ca. 5.6 ‰). Still, low Ce/Pb ratios and elevated Cs concentrations indicate that the basaltic magmas were contaminated by crust. During their ascent to the surface, the magmas evolved by crystal fractionation and crustal assimilation, however, neither process can adequately explain the petrogenesis of hawaiite and tholeiite compositions that were erupted contemporaneously at Sheridan Bluff. Our preferred scenario is that primary magmas of each type were produced by different degrees of partial melting from an enriched mantle source containing hydrous phases (e.g., amphibole). The nearly simultaneous generation of lower degrees of melting to produce alkaline types and higher degrees of melting to form tholeiite was most likely facilitated by the detachment and dehydration of metasomatised mantle lithosphere.

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Englacial tephra layers at Mt Melbourne (Antarctica): implications for recent volcanic activity

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Mt. Melbourne is a quiescent stratovolcano (2732 m a.s.l.) located along the western coast of the Ross Sea at about 42 km from the Italian Mario Zucchelli Station (MZS) and 33 km from the South Korean Jang Bogo Station (JBS), between the Tinker Glacier to the north and the Campbell Glacier to the south. It is largely covered by ice except for some peripheral areas and several scoria cones, lava domes, viscous lava flows, lava fields that are exposed from the summit along the upper flanks. The summit area is characterized by a ca. 1 km wide crater filled by snow and surrounded by several scoria cones. The summit area is also characterized by the presence of heated ground and fumaroles both in the crater and 250 m downslope. According to Lyon (1986), the most recent volcanic activity of Mt. Melbourne occurred between 1862 and 1922 on the basis of the depth of two tephra layers in the ice. Apart from the fumarolic activity at the summit crater, no other type of volcanic activity has been directly observed since 1985 when MZS became a permanent base. During the XXXII Italian expedition and in the framework of the ICE-VOLC project (www.icevolc-project.com) black, sub-horizontal tephra layers were discovered outcropping in a ca. 50 meter high ice cliff on the eastern flank of Mt Melbourne. Sampling was performed by Italian alpine guides. We present data on texture, major- and trace-element composition performed on single glass shards (WDS-EPMA and LA-ICP-MS) on these tephra providing their geochemical fingerprinting and correlation with the volcanic sources. Morphological and textural characterization give information on the volcanic activity and on the basis of the ice thickness between the tephra layers, we give inferences about the age of the eruptions that have produced these deposits.

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An uncommonly well-exposed Miocene caldera interior at Mason Spur, Antarctica: unusual trachytic spatter-rich lapilli tuff facies amid evidence for voluminous eruptions

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Near-continuous exposure, 10 km laterally and >1 km vertically, at the Miocene-aged Mason Spur eruptive centre (Antarctica) reveals a thick (hundreds of metres) caldera-filling unit (trachytic pyroclastic member) dominated by trachytic ignimbrites and breccias (lithofacies A) and abundant coeval trachytic intrusions (trachytic intrusive member). This trachytic pyroclastic member was extremely voluminous and records environmental conditions at the time of its eruption. This eruption was significant enough to have affected all of Antarctica and occurred immediately after the mid Miocene Climatic Optimum, during the descent into a deeper icehouse world. This time is critical for understanding how modern global warming and sea-level changes will affect the planet.

Within the trachytic pyroclastic member, a distinctive trachytic, Miocene (c. 12 Ma), spatter-rich pyroclastic density current deposit (ignimbrite), > 80 m-thick (lithofacies B), was studied. Pyroclastic deposits have been recorded at several localities worldwide that contain both a pumiceous matrix and dense fluidal spatter clasts. These previously described deposits routinely document lava spatter and that the spatter is generally glass-free. Understanding the eruptive conditions responsible for mixing together these two very different clast types has implications for interpreting the depositional processes and dynamics of explosive eruptions and volcanic hazard assessment. We use the exceptional outcrops at Mason Spur, Antarctica, to shed light on this issue.

Key field characteristics of the Mason Spur ignimbrite include the following: 1. spatter clasts that are spectacularly ribbon-like in cross-section but have predominantly flattened disk shapes; 2. conspicuous fluidal spatter clasts are composed of black obsidian up to 2 m-long, supported in a pale pumiceous lapilli tuff matrix; 3. spatter clasts are commonly orientated at less than the angle of repose; 4. massive bedding; 5. erosive base; 6. apart from a paucity of spatter in the basal 1–2 m, no vertical or lateral grading of spatter abundance; 7. poor sorting and a lack of size grading in the matrix, and; 8. the spatter and pumiceous lapilli have slightly different (trachytic) compositions.

This ignimbrite (lithofacies B) was rapidly erupted onto a gently dipping (c. 12°) palaeo-surface that probably included either a shallow lake or possibly snow, patches of wet ground (possibly puddled) or a stream. Water was ingested by the overflowing pyroclastic density current, as steam, and caused brittle fracture of some spatter clasts, many of which disintegrated to form diffuse patches rich in lapilli-size obsidian fragments, but most spatter retained a fluidal shape and escaped profound fracturing. Although several general models have been proposed for the origin of spatter-rich ignimbrites, our favoured interpretation for this Mason Spur example involves the eruption of dense, hot spatter and pumiceous lapilli tuff from two separate co-eruptive vents, with mingling of the contrasting pyroclast types taking place when spatter clasts from a lava fountain were entrained in a pyroclastic density current independently sourced in a low collapsing column. The distinctive highly attenuated shapes of the spatter, each with relatively smooth surfaces, are probably a consequence of the trachytic spatter-forming magma being very fluid, with a viscosity similar to that

of fluidal phonolite.

Well-exposed caldera interiors are uncommon and that at Mason Spur helps to understand eruption dynamics associated with a complex, large island volcano. The results of this study will help to elucidate interpretations of other, less well exposed, pyroclastic density current deposits elsewhere in Antarctica and globally.

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Evolution of Alkalic Magma Systems: Insight from Coeval Evolution of Sodic and Potassic Fractionation Lineages at The Pleiades Volcanic Complex

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The magmatic evolution of The Pleiades, a Quaternary alkalic volcanic complex in Northern Victoria Land (NVL), Antarctica, is investigated using major and trace element, and Sr, Nd and Pb isotopic data. The volcanic rocks can be subdivided into two distinct magmatic lineages based on petrography and whole-rock compositions: (1) a sodic silica-undersaturated lineage with abundant kaersutite phenocrysts and (2) a potassic and mildly-alkalic, silica-saturated to slightly undersaturated lineage containing olivine phenocrysts but no kaersutite. The pressure–temperature paths estimated by clinopyroxene–liquid thermobarometry are similar in each lineage. Mass balance calculations using whole-rock and mineral compositions show that kaersutite fractionation without olivine has played a major role in magmatic differentiation of the sodic lineage, whereas the compositional variations of the potassic lineage can be ascribed to fractionation of an assemblage of plagioclase, clinopyroxene, olivine, titanomagnetite and apatite, combined with about 10% lower crustal assimilation. The higher 87Sr/86Sr (> 0.7035), lower 143Nd/144Nd (< 0.51285) and 206Pb/204Pb (< 19.3) ratios of the evolved potassic lavas compared to the mafic lavas support crustal assimilation. The mafic lavas from both lineages are characterized by elevated 206Pb/204Pb (>19.5) ratios and narrow ranges of 87Sr/86Sr (0.70313-0.70327) and 143Nd/144Nd (0.51289-0.51290) ratios, which is consistent with a high μ-like (HIMU, where μis an initial 238U/204Pb ratio) component typical of Cenozoic volcanic rocks in Antarctica and Zealandia. This HIMU-like isotopic signature of The Pleiades volcanic rocks, together with elevated Nb concentrations and negative K anomalies in primitive mantle-normalized diagrams, suggests an amphibole-bearing metasomatized lithospheric mantle source. We suggest that the primary magmas of the two lineages were formed by partial melting of metasomatic hydrous veins in the lithospheric mantle with varying degrees of reaction with the surrounding, anhydrous peridotite. The drier potassic magma experienced greater peridotite assimilation relative to the more hydrous sodic magmas. This hypothesis is supported by lower contents of Al2O3, TiO2,K2O, Rb and Nb in the mafic potassic lavas compared to the sodic ones. This initial difference was intensified by crustal assimilation in the potassic magma suite, resulting in a silica-saturated alkalic trend which is distinct from the trend of the sodic silica-undersaturated alkalic magmas.

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Geoelectric structure of Mt. Melbourne, Antarctica from magnetotelluric data

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Mt. Melbourne is a massive volcano in the Victoria Land, Antarctica. A previous study on seismic tomography has revealed the low-velocity zones indicating the partial melting in the upper mantle near the volcano. In this study, we investigate the crustal structure underneath Mt. Melbourne using the magnetotelluric (MT) sounding data. To overcome the problems due to the high contact resistance of snow cover and the low temperature, we developed a new MT system of low power consumption with high internal impedance. The MT soundings were conducted at 14 sites across the volcano and, in addition, a long-term MT field monitoring was operated for ~100 days at a site to investigate the temporal variation of noise environment and subsurface geoelectric property. The quality of MT data is closely correlated with the wind speed over MT sites indicating the most severe noise source is the static electricity of snow drift driven by wind. A timeseries processing scheme adopting the wind speed as a weighting function successfully reduces the noise by the snow drift. The snow/ice thicknesses over the volcano are less than several hundred meters similar to the airborne radar survey of ISODYN-WISE project. The resistivity of bedrock is about 100 – 500 ohm-m indicating conductive volcanic rocks. Our inversion result shows a highly conductive body at a depth of about 2 km located to the south from the center of volcano. The depth of conductive body is coincident with the location of the ground deformation source figured out by previous long-term surface tilt monitoring. The existence of highly conductive body under the Mt. Melbourne indicates there is a molten melt magma chamber or a partial melting zone.

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Shield Nunatak: An englacial tuya in the Melbourne volcanic field

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Lithological features of Shield Nunatak, an alkali basaltic glacio-volcanic tablemount in the Melbourne volcanic field, are studied in detail based on description of outcrop sections and petrographic investigation. Key lithofacies identified in this study are 1) lava flows and pillows, 2) agglutinated spatter/scoria, 3) massive intrusions, 4) curvy linear dykes with peperitic rinds, 5) massive (or stratified) hyaloclastite, 6) massive (or stratified) tuff, 7) cross-stratified sand (or gravely sand), and 8) bedded mud (or silt-streaked mud) containing granule lens and trains. Lines of evidence indicate sub-lacustrine sedimentary processes and vigorous magma-water (or lava-water) interactions, suggesting that Shield Nunatak was developed as an englacial tuya under seald to partly sealed glacio-hydrologic conditions. In the early stage of the Shield Nuantak formation, eruptions took place in an englacial sub-lacustrine environment. By vigorous interaction between erupting magma and lake water, the early eruptions generated a range of subaqueous volcaniclastic sediment gravity flows and suspended loads which piled up a thick cross-stratified volcaniclastic sand and bedded mud sequence. As the volcanic edifice grew up, eruptions became more effusive, generating lava flows, pillows and hyaloclastic deposits along with shallow emplacement of mafic intrusions. Ash accretion textures found in tuff interbeds suggests subaerial eruption plumes and/or PDCs from partly emergent vent. In the latest stage, the magma-water interaction was no more available as the volcano became fully emergent above lake level. Until the termination of the volcanism, lava-fountaining eruptions continued to develop a spatter/scoria cone at the top of Shield Nunatak.

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Death of an Arc: Exploring the 20 Ma cessation of the Antarctic Peninsula volcanic arc

Alex Burton-Johnson[1]

Following breakup of the Gondwanan supercontinent and its associated LIP magmatism at 188-162 Ma, the Antarctic Peninsula developed into a continental arc with extensive magmatism along its 2000 km length (Burton-Johnson and Riley, 2015). Through the Cenozoic, the spreading ridge between the subducting Phoenix and Pacific oceanic plates collided parallel to the continental margin and with each ridge-trench collision subduction and associated magmatism ceased progressively northwards. The final region of subduction and arc magmatism was the South Shetland Islands where arc magmatism continued until between 20-14 Ma in to the Miocene to be followed by alkaline volcanism after 3 Ma.

However, despite the apparent Miocene end of arc magmatism, geodynamic models indicate that subduction beneath the South Shetland Islands continued until 4 Ma. To investigate the cause of this disparity we present new field data, geochemistry, and geochronology from the South Shetland Islands, and present a revised geodynamic model of the Scotia Sea development.

A046

Session05: The Neoproterozoic to Cambrian Orogenies and their precursors in Antarctica and adjacent continental blocks

The architecture of late Neoproterozoic – Cambrian Prydz orogen from new U–Pb zircon data, and some implications on its formation

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The ca 580−500 Ma Prydz Orogen has been commonly considered to include the Princess Elizabeth Land and southern and central Prince Charles Mountains (PCM). The Prydz Orogeny most strongly (high-grade metamorphism and ductile deformations largely concentrated within E−W high-strain shear zones) affected the eastern Prydz Bay coast (except Vestfold Block) and the Grove Mountains (where they were pervasive) while in the northern PCM and Mawson Coast Prydz-age events have been not documented or occurred as local thermal/shear overprint. Thus the intensity of the Prydz-age tectonism weakens from south-east (Grove Mountains) to north-west (Mawson Coast). New LA-ICP-MS U−Pb data on detrital zircons from high-grade ca 1000 Ma paragneisses in central PCM, eastern Amery Ice Shelf, and Rauer Islands (the Rayner Province) reveal clusters of ages of ca 2500–2100 Ma (predominate), ca 2100−1600 Ma (subordinate), or both. Provided most magmatic activities in the Rayner Province were ca 1500–1000 Ma, the lack of zircons with such ages implies sedimentation pre-dated ca 1500 Ma. This points out to the wider presence of continental crust predating juvenile Rayner precursors. The source of these largely Palaeoproterozoic detrital populations may not be easily found within this sector of East Antarctica. The only known exception is the early Palaeoproterozoic Lambert Terrane in the Ruker Province, formed between ca 2500–2100 Ma, but the late Palaeoproterozoic (ca 2100–1600 Ma) grains must have been derived from another source region. Noteworthy most of these grains correspond in age to Columbia supercontinent formation, the process best exemplified in Central India and Western Australia. Thus, tectonothermal processes in Central Indian Tectonic Zone (Singhbhum Orogeny, ca 2200–2000 Ma, Saptura Orogeny, ca 2100–1800 Ma; Mohanty, 2012, 2015) may have provided zircons found within the Rayner Province. This confirms an earlier suggestion (op. cit., S.Boger) that most of the Rayner Province belongs to the Indo-Antarctica and was accreted onto the Australo-Antarctica or a cryptic landmass. The timing of this process was most likely late Meso- – early Neoproterozoic, rather than late Neoproterozoic – Cambrian, as the intensity of corresponding tectonothermal processes would increase southwards, opposite to the observed. Thus the Prydz-age tectonothermal processes might have been caused by collision with a suture lying southwards with leading role of mantle upwelling/underplating and horizontal movements with indentor (Grove Block) – escape (Vestfold Block) tectonics defining the observed orogen architecture.

However, ca 1700 Ma event has been documented, although scarcely, within the Lambert Terrane (Mikhalsky et al., 2010) and ca 2100−1830 Ma detrital zircons have been found in Proterozoic metasediments in the Ruker Terrane (Phillips et al., 2006). These findings allow a local, albeit yet cryptic source for ca 2100−1600 Ma zircons in metasediments. Thus an alternative model suggests extension of the early Precambrian crust (Ruker Province) as far north as central PCM and Amery Ice Shelf, largely covered by Proterozoic supracrustals. This implies the Prydz-age suture may be concealed by Lambert Glacier – Amery Ice Shelf Rift System. The corresponding high-grade metamorphism may be caused by extensional tectonics rather than collisionally overthickened crust.

A067

Session05: The Neoproterozoic to Cambrian Orogenies and their precursors in Antarctica and adjacent continental blocks

Proterozoic magma activities and formation of collision zone in the Sør Rondane Mountains, eastern Dronning Maud Land, East Antarctica

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The formation of the Gondwana supercontinent resulted from the collision of the East- and West-Gondwana continents. The time of collision event is regarded as geological time scale from the late Neoproterozoic to early Cambrian. The Sør Rondane Mountains (SRM), eastern Dronning Maud Land, East Antarctica, are situated within the Pan-African suture zone related to the East- and West-Gondwana collision. The geology of SRM is divided into the northeast terrane (NE terrane) and the southwest terrane (SW terrane) in terms of lithology and metamorphic processes. These two terranes were welled during the Late Proterozoic (c. 640 Ma). The NE terrane is composed mainly of metamorphic rocks, whereas the SW terrane consists of metamorphic rocks (Layered gneiss complex) and the tonalite (Tonalite complex). Post-kinematic intrusive rocks include granitoids, lamprophyres, and dolerites occurring in the SW and NE terranes.

The Layered gneiss complex in the SW terrane ubiquitously bears metamorphosed igneous rocks with granitic compositions. These igneous activities started at c. 1100 Ma and ceased at c. 650 Ma having two pulses of 1000 to 900 Ma and 750 to 770 Ma. The Tonalite complex consists mainly of the tonalite associated with the microgabbro occurring as magmatic enclaves and dikes. Although the rocks from Tonalite complex underwent low-grade metamorphism, zircon U–Pb dating indicate that the main igneous activities of the Tonalite complex occurred during 930 to 1000 Ma. Granitoid magmas are generally produced by partial melting of middle and lower crusts.

The Nd isotope data of granitoids, therefore, give important information for evolution of continental crust. The granitoids from the SW terrane show positive epsilon Nd values corrected to each intrusive age. Therefore, the SW terrane as a whole was derived from a juvenile crust during Neoproterozoic time from 1100 Ma to 650 Ma. The plausible tectonic setting for the formation of the SW terrane would be an oceanic arc. The SW terrane was situated at plate convergent boundaries for almost 450 million years. On the other hand, the epsilon Nd values of post-kinematic granitoids, ranging from 620 to 500 Ma, possess almost zero to less than zero. It means that the old continental materials contributed to the formation of the post-kinematic granitoid magmas. The post-kinematic lamprophyre and dolerite intruded into NE and SW terranes. The geochemical characters of the lamprophyre and dolerite are similar to those of volcanic arc and oceanic island basalts, respectively. The geology of SRM is considered to change to a within plate setting from a plate convergent boundary after amalgamation of the NE and SW terranes. In this scenario, the post-kinematic magmatism would be caused by up-welling of mantle asthenosphere as an acting heat source.

A072

Session05: The Neoproterozoic to Cambrian Orogenies and their precursors in Antarctica and adjacent continental blocks

THE CAMBRIAN UPLIFT HISTORY OF W. DRONNING MAUD LAND, ANTARCTICA : NEW 40AR/39AR AND SR AND ND DATA.

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40Ar/39Ar laser step heating data from Mesoproterozoic basement gneisses from Kirwanveggan, Western Dronning Maud Land, Antarctica (WDML), reveal significantly different ages for biotite and hornblende with ages varying between 497Ma and 868Ma and 480 Ma and 1067Ma respectively. In contrast data for biotite and hornblende from Sverdrupfjella, WDML, show ages varying between 326Ma and 547Ma and 450 Ma and 550Ma respectively. Whereas the broadly similar ages for hornblende and biotite pairs from Sverdrupfjella are consistent with fairly rapid uplift of Sverdrupfjella, the differences in age between biotite and hornblende pairs from Kirwanveggan imply decreasing uplift southwards through Kirwanveggan.

Biotite ages in Sverdrupfjella and Kirwanveggan are similar to and younger than reported ages of deposition of the Urfjell Group clastic sediments, with the Urfjell Group constraining the southern limit of uplift, erosion and deposition at ~530Ma. Similarly, ~480-500Ma syntectonic undeformed granitic veins with top to the SE emplacement and younger than the Urfjell Group, were intruded at least 180kms to the NE in Sverdrupfjella.

Radiogenic isotope characteristics of the Urfjell Group sedimentary rocks are similar to basement gneisses from Kirwanveggan, eastern Sverdrupfjella, Gjelsvikfjella and Central Dronning Maud Land (CDML). In contrast detrital zircon patterns of the Urfjell Formation clastic sediments suggest derivation from a source similar to lithologies from Central Dronning Maud Land, ca. 350-600km away.

Tectonic analysis of Dronning Maud Land, involving published and new Sr/Nd radiogenic isotope data, along with published SHRIMP U/Pb zircon data from granite veins, P-T-t estimates and structural analysis allow the interpretation that eastern Sverdrupfjella, Gjelsvikfjella and CDML comprise a nappe complex which has been emplaced toward S-SE over western Sverdrupfjella at ca. 480-500Ma, the timing being constrained by the age of syntectonic granitic intrusions and rapid uplift reflected by the 40Ar/39Ar data. The emplacement of the nappe complex would place a potential source for the Urfjell Group significantly closer to its basin depository at most 140km away at present day erosion levels.

The tectonic analysis is consistent with published aeromagnetic and gravity data from WDML in which strong magnetic anomalies correlate with high strain zones characterized by thrust fault or strike slip senses of shear. Areas of crustal thickening resulting either from tectonic duplication or younger basin development correlate with areas of stronger gravity anomalies and crustal thickness.

The reach of the Kuunga Orogeny in WDML is limited to central Kirwanveggan, with its southern limit represented by the Urfjell Group sedimentary basin at ca. 530Ma and not to Heimefrontfjella.

Recognition of the top-to-the-SE deformation in the Maud Belt, is restricted to Sverdrupfjella, indicating that the deformation related uplift did not affect Kirwanveggan. The recognition of relatively old 40Ar/39Ar from hornblende in southern Kirwanveggan suggests that the dominant planar fabrics recognized in Kirwanveggan are Mesoproterozoic in age.

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Ediacaran-Cambrian metamorphic evolution of the granulite terranes in the Larsemann Hills, East Antarctica: Response to the assembly of the East Gondwana.

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Located in the Prydz Bay belt, East Antarctica, the Larsemann Hills is basically composed of granulite facies meta-sediments and orthogneisses that have recorded two geothermal events, in Early Neoproterozoic and Late Neoproterozoic to Early Paleozoic, respectively. The tectono-metamorphic history of high grade terreanes can be complex, especially when there is overprinting of multiple tectono-thermal events. Granulite of different characteristics and compositions were investigated by integrating petrology, phase equilibria modeling and in situ geochronology in order to decipher the metamorphic evolution of the granulite terranes in the region. The pelitic granulites basically have a representative mineral assemblage of garnet, sillimanite, quartz, spinel, biotite, plagioclase, K-feldspar and cordierite, though the mineral modes vary from sample to sample. The granulite of graywacke protolith has a mineral assemblage of garnet, orthopyroxene, plagioclase (antiperthite), biotite, minor K-feldspar and cordierite. Phase equilibria modelling was conducted for the samples in the model system Na2O–CaO–K2O–FeO–MgO–Al2O3–SiO2–H2O–TiO2–O (NCKFMASHTO). The results suggest that the granulites have undergone high temperature metamorphism at P-T conditions of ~ 5-6 kbar and >850°C. The geochronological analyses of zircon and monazite revealed an age span from ~ 560Ma to 510 Ma. NanoSIMS analyses of in situ zircon enclosed in spinel yielded an age of ~ 530 Ma, before which the decompression represented by the development of spinel and cordierite must have initiated. Responding to the assembly of the East Gondwana, the terranes in the Larsemann Hills underwent protracted metamorphic process. The results help to further constrain the tectonic setting in which the rocks have evolved and hence the evolution of the East Antarctica.

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Early Neoproterozoic granulite facies metamorphism and possible Cambrian reworking at Mount Brown, East Antarctica

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Mount Brown is a unique inland outcrop between Prydz Bay and Denman Glacier that provides useful insights into the tectonic evolution of the Indian Ocean sector of Antarctica. The bedrock at Mount Brown predominantly consists of felsic orthogneisses, with subordinate amounts of mafic granulites, anatectic paragneisses and pegmatite dikes. These metamorphic rocks have a regional NE–SW to NNE–SSW-trending gneissic fabric that gently dips towards the northwest. Mafic granulites are mainly two-pyroxene granulites and locally contain garnet. Coronal and symplectic textures are widely developed, indicating an early mineral assemblage of garnet + orthopyroxene + clinopyroxene + hornblende + biotite + plagioclase + quartz and a late assemblage of garnet + clinopyroxene + hornblende + biotite + plagioclase + K-feldspar + quartz. Paragneisses are mainly garnet–biotite–plagioclase gneisses and also show reaction textures. The early mineral assemblage is garnet + orthopyroxene + biotite + plagioclase + quartz, and late assemblage is garnet + biotite + plagioclase + K-feldspar + quartz. P-T pseudosection calculations in the system NCFMASHTO (Na2O–CaO–FeO–MgO–Al2O3–SiO2–H2O–TiO2–Fe2O3) for a mafic granulite and NCKFMASHTO (Na2O–CaO–K2O–FeO–MgO–Al2O3–SiO2–H2O–TiO2–Fe2O3) for a paragneiss suggest that the early metamorphism reached peak P–T conditions of 830–870°C and 7–8 kbar, followed by a late near-isobaric cooling to 760–830°C and 7–8.5 kbar. SHRIMP U–Pb zircon dating reveals the emplacement of mafic granulite and felsic orthogneiss protoliths at ~1490–1400 Ma, sedimentation of paragneiss precursors after ~1250 Ma, and subsequent high-grade metamorphism accompanied by partial melting at ~920–900 Ma. Taking into account zircons occurring in areas of retrograde reaction textures in paragneisses also yield early Neoproterozoic ages, we infer that the above anticlockwise P–T path was generated by a single early Neoproterozoic metamorphic cycle. However, SHRIMP U–Pb dating on in situ monazite from paragneisses indicates that Pb loss is common although the majority of spot analyses yield ages close to ~900 Ma. A fluid flow event of ~650 Ma was also recognized from the dated samples. Moreover, SIMS U–Pb rutile dating and 40Ar/39Ar biotite dating yield cooling ages of ~515 Ma and ~520-505 Ma, respectively. This suggests that Mount Brown did not seem to escape the reworking of Cambrian tectonothermal event that is widespread in East Antarctica.

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Sequences of the Metamorphic Complex, Tectonic Framework and Deformation Evolution in Larsemann Hills, Eastern Antarctica

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The Larsemann Hills, located at the core zone of the Prydz Bay, contains one of the largest area of exposed rocks in eastern Antarctica. Previous studies have built the petrology-metamorphism-chronology frame of the Larsemann Hills. The authors mapped a 1:25000 geological map of the Larsemann Hills during their research with the Chinese National Antarctic Research Expedition from December 2012 to February 2013. The sequences of the metamorphic complex, tectonic framework and deformation evolution in Larsemann Hills are clarified based on this geological mapping. The metamorphic complex in the Larsemann Hills, which is called the Larsemann Group (Pt1L) in this study, is layered and mainly para-metamorphic rocks. The Pt1L is divided into layered gneiss Formation (Pt1L(gn)), pelitic-quartz-feldspathic gneiss Formation (Pt1L(p-gn)), magnetite-pelitic-quartz-feldspathic gneiss Formation (Pt1L(mp-gn)), migmatized quartz-feldspathic gneiss Formation (Pt1L(a-gn)), mafic granulite formation (Pt1L(mg)), fine-grained gneiss (Pt1L(fgn)). The age of the Larsemann Group is Paleoproterozoic according to the preexisting isotopic data and our detrital zircon age data. The Larsemann Hill is NE-NEE striking and is a regional tight syncline with NE-NEE-trending axis. There exists earlier NNW axial trend folds and the low-angle ductile shear zone with NNE extension which developed between the Pt1L(mg) and the underlying Pt1L(gn). Four stages of metamorphism-magmatism-deformation events are recognized: Grenvillian regional metamorphism (D1), Pan-African metamorphism, bedding migmatization, emplacement of granitoid magma, low-angle ductile shear deformation (D2), NW-SE-striking compression and the formation of tight folds with NEE-striking axis (D3), brittle fracturing and high-angle normal faults (D4).

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Ross Orogen: One-hundred forty-five million years of Gondwana-margin convergent plate evolution

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The Ross Orogen, one of the world's longest orogenic belts, was active during the latest Neoproterozoic and early Paleozoic amalgamation of Gondwana. Following Neoproterozoic rift separation of East Antarctica from Laurentia during breakup of Rodinia, the development of an Andean-style convergent plate boundary led to a long-lived Ross orogenic cycle from ca. 615-470 Ma along the active Gondwana margin of East Antarctica. Subduction occurred in response to closure of the Mozambique Ocean and collision within the East African Orogen. The Ross belt was continuous with the Delamerian (Australia), Cape (South Africa) and Pampean (South America) orogens, and it is generally coeval with the Kuunga system traceable from Dronning Maud Land to Wilkes Land. The main spine of the modern Transantarctic Mountains (TAM) is underpinned by deformed rocks and a granitoid batholith of the Ross Orogen, whose architecture is both controlled by the preceding rift geometry and influenced all subsequent geologic history. The convergent plate-boundary setting of the Ross belt produced a prolific, largely calc-alkaline, continental-margin magmatic arc constructed within Proterozoic to early Paleozoic crust, thick marginal-basin siliciclastic deposits, ultra-high pressure eclogites locally, and structures indicative of oblique convergence and transpression. A new compilation of geologic and age data from northern Victoria Land to the Pensacola Mountains shows that major orogenic trends—including timing of events, pace and character of magmatism, deformation patterns, metamorphic regimes, and sedimentary provenance changes—can be attributed to variations in convergent-margin dynamics over a long-lived Ross orogenic cycle. Although the Ross belt appears to mark continuous underflow of paleo-Pacific oceanic lithosphere beneath continental East Antarctica, orogenic patterns indicate differential sea-floor spreading about a pole of rotation near South Africa in a Gondwana fit, yielding faster subduction of older lithosphere to the north. This led to significant variations in the timing and character of events along the length of the orogen. Key elements of the dynamic system include: (1) inherited rift-margin geometry exerted a major control on all orogenic processes, as shown by contrasts in magmatic, metamorphic and deformational patterns; (2) sinistral-oblique subduction, recorded by partitioned and/or transpressional structures; (3) diachronous onset of magmatism, from ~580 Ma in northern Victoria Land to ~510 Ma in the Pensacola Mountains; (4) variable influence of overlying cratonic crust during magma evolution, ranging from mantle-dominated signatures in northern and southern Victoria Land, to strong cratonic signatures in the central TAM, and continentally-influenced rift-type magmas in the southern TAM; (5) periodic intra-arc contraction and extension linked to varying magmatic styles; (6) HP-UHP metamorphism restricted to domains characterized by arc/back-arc construction and subsequent rapid thickening; and (7) a flood of syn-orogenic siliciclastic sediment with a dominantly Ross Orogen provenance, signaling initial orogenic activity in many areas. Although the Ross Orogen formed at an Andean-style margin, subducting oceanic lithosphere did not everywhere encounter continental lithosphere; in northern Victoria Land, plate convergence evolved from sub-cratonic to a broader forearc/back-arc/arc system constructed on oceanic upper-plate lithosphere, whereas in the central TAM deformation and magmatism were strongly influenced by the involvement of reactivated Archean-Mesoproterozoic upper-plate continental and extended rift-margin crust. A better understanding of the tectonic history of the Ross Orogen in space, time and process will emerge from further orogen-scale comparisons of crustal conditions, magma sources, tectonic displacements, sediment sources, and cooling and exhumation histories.

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Investigating the geological terrains hidden beneath the thick ice cover of Princess Elizabeth Land, Antarctica

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Princess Elizabeth Land of East Antarctica is geologically one of the least studied terrains in East Antarctica, primarily because of very thick ice cover and limited available rock outcrops. It is a key geological link preserving records of formation, evolution, and break-up of Rodinia and Gondwana. Apart from the direct geological investigations and indirect geophysical surveying, backtracking the source area geology from the sediments derived through oceanic drilling has been recognized as an important tool to examine the sub-ice geology. Continental shelf, slope and rise areas of passive continental margin have sediments derived from the terrestrial environments and act as a reservoir to trace the source geological terrain and its paleoclimatic conditions. Offshore of Princess Elizabeth Land (Prydz Bay) were drilled in 1980 under ODP Leg 119. A variety of glacial sediment types, including lodgement till and glaciomarine sediments were recovered from these sites. The main objective of this drilling was to provide information about the pre-glacial depositional environments and paleoclimate record in this segment of east Antarctica and the age the separation of east Antarctica from India.

Present work focuses on Site 740 (part of Leg 119) drilled on the continental shelf of Princess Elizabeth Land of east Antarctica. The site was previously considered to be mainly fed by the Lambert Rift sediment flushing but considering the gyre water current movement; sediment supply from the proximal PEL interior has also been speculated. Provenance study for reconstructing the sub-ice geology in this proximal zone is attempted in our work.

Electron Probe Micro-Analyzer (EPMA) and Scanning Electron Microscopy (SEM) analyses of heavy mineral assemblage from site 740 show the dominance of garnet followed by amphibole over rest of the phases. Aluminosilicates, amphibole, pyroxene, ilmenite, and iron oxides are the other phases identified from mineral chemical analyses. Garnet of more than one range of compositions is present. Metamorphosed orthogneisses of granulite facies in the provenance, possibly of a mafic protolith, are indicated by the presence of pyrope garnet (Py56Alm28Gr15Sp1) and clinopyroxene. Almandine (Alm80Py19Gr1Sp0) with aluminosilicate (kyanite from textural features) indicates the presence of intermediate to high-pressure metapelitic sourcing of minerals. Possible sources are mafic-ultramafic rocks, likely to be metamorphosed as indicated by rest of the heavy mineral assemblage. Presence of large grain of monazite (~100 µm) suggests its metamorphic origin. Fe-Mg chlorite could either be on account of extensive retrogression of medium to high-grade assemblages or polymetamorphic terrains accreted together. Heavy mineral data indicates the presence of a medium to high-grade metamorphic terrain present in the interior of the Princess Elizabeth Land between the coordinates 73° E and 87°E This inference is correlated with the recent geophysical investigations.

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Isotope geochemistry of metacarbonate rocks in continental collision zones as proxies for estimating the sedimentation age and understanding the tectonic setting of deposition

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Determination of depositional ages and tectonic environment of metasedimentary sequences in orogenic belts are of prime importance in understanding the formation and evolution of supercontinents. Although depositional ages can be bracketed approximately between the youngest protolith age of detrital zircons and metamorphic ages, obtaining the accurate depositional age and tectonic setting are difficult tasks. In order to overcome this, a detailed study on strontium, neodymium and lead isotope geochemistry of metacarbonate rocks from different East Gondwana continents were considered in this study. In particular, metacarbonate rocks from East Antarctica and Sri Lanka were studied in detail. Metacarbonate rocks are thought to have deposited directly from extinct paleooceans. The isotopic systems studied have distinct residence and mixing time in seawater, and are also controlled by the input from surrounding continents. We present here a model on the closure of the "Mozambique Ocean" prior to the final amalgamation of the Gondwana supercontinent purely based on the isotope geochemistry of metacarbonate rocks.

In order to obtain primary sedimentary geochemical information for the study area an extensive geochemical screening protocol for identifying post-depositional alterations, using oxygen isotopes, trace elements and REE + Y patterns was followed. As a first step, we measured oxygen and carbon isotope ratios of the metacarbonate rocks to choose the least altered sample, which could possibly preserve the marine chemical composition at the time of sedimentation.
In general, the metacarbonate rocks have positive oxygen isotopic composition, suggesting that these rocks were not affected by external infiltration of fluids during diagenesis, dolomitization or metamorphism. Unmetamorphosed carbonate rocks deposited in the Proterozoic have carbon and oxygen isotopic compositions of 0±2‰ -12 to +10‰ and + 25 ± 5‰, respectively. Strontium isotope chemostratigraphy was applied for the selected samples. Depositional ages were estimated using established strontium isotope evolution curves. By using the εSr vs. εNd cross-plots it was possible to distinguish the typical seawater-rock mixing relationship in metacarbonate rocks associated with continents and oceanic crusts. Pb isotope analysis was carried out for the first time for the metacarbonate rocks in the EAAO belt. The results indicate that Pb isotopic compositions showed significant difference within a single terrane. This might be due to the difference of initial composition, as well as the relationship to depositional basin and seawater composition. The Sr-Nd-Pb isotopic composition in metacarbonate rocks suggests interaction between the oceanic crust and carbonate rocks on the Wanni side whereas on the Vijayan side, carbonate sedimentation was accompanied by interaction with cratonic continental crust.

Our results confirm the evidence of an oceanic island arc system and peripheral oceans to continents before the formation of the Gondwana supercontinent in the Neoproterozoic. By applying a multi-element isotope geochemical approach on chemostratigraphically well constrained metacarbonate rocks collected from continental collisional zones, and comparing the data with basement rocks from various neighbouring Gondwana continents, regional affinities could be established. Sr, Nd and Pb isotopic compositions provide important information about the depositional settings of sedimentary

rocks and provide key information about the surrounding terrains of oceanic and continental affinities during the time of deposition. This can lead to a better understanding of paleo-tectonic settings of crustal fragments that assemble to form supercontinents.

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Dronning Maud Land - Enderby Land connection: views from metamorphic and geochronologic records in Rayner and Western Rayner Complexes, East Antarctica

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Neoproterozoic to Cambrian orogenies are widely distributed at the Indian sector of East Antarctica. The easternmost part of Dronning Maud Land is the Lützow-Holm Complex that is believed to be typical of continental collision metamorphic belt of which amphibolite to granulite (partly UHT) facies regional metamorphism and clockwise P-T trajectory, supported by the widespread occurrence of sillimanite with prograde kyanite and retrograde andalusite (e.g., Hiroi et al., 1983). A major 550-520 Ma metamorphic age episode was indicated by SHRIMP zircon geochronology (e.g., Shiraishi et al., 1992; 1994; 2003) and was recently refined to include early metamorphic events at >600 Ma (Hokada and Motoyoshi, 2006; Dunkley et al., 2014). Further to the east, the Western Rayner Complex in Enderby Land, of which granulite-facies and partly UHT metamorphism (Motoyoshi et al., 1994, 1995) and 2400-700 Ma protolith and 540-520 Ma metamorphic ages were reported (Shiraishi et al., 1997). The neighboring Rayner Complex is characterized by >2500-1000 Ma protolith and 980-910 Ma granulite-facies metamorphic ages. The boundary between the Rayner and the Western Rayner Complexes has been not clearly defined until Horie et al. (2016) obtained 934-894 Ma SHIRMP zircon U-Pb ages from Mt. Lira, Condon Hills and Mt. Yuzhnaya regions. Hiroi (unpublished data) also demonstrated contrasting metamorphic P-T evolution among the Mt. Lira, Condon Hills and Mt. Yuzhnaya regions. Recent Japanese Antarctic program made short visits and sampling at several small nunataks in the Rayner and the Western Rayner Complexes boundary zones. We will report and discuss the update of the characteristic features of the Rayner and the Western Rayner Complexes, that are of implications for Dronning Maud Land –Enderby Land connection.

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Letters from deep crust - What we received from Antarctica and Gondwana

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Japan commenced its scientific activities in Antarctica in 1956. Among many observation items, geological field survey has been one of the main items from the beginning of the Japanese Antarctic history. During the past 60 years, about 120 geologists in total have taken part in the Japanese Antarctic Research Expedition (JARE) to conduct geological surveys in a part of the East Antarctic Shield. The regions around Japanese Syowa Station, namely Lutzow-Holm Bay, Prince Olav Coast, and the Yamato and Belgica Mountains, have been mapped by late 1980s and 30 sheets of Antarctic Geological Map Series were published by the National Institute of Polar Research. After 1983, JARE expanded the survey area into the Sør-Rondane Mountains to the west to conduct geoscience programs including geology. The Sør-Rondane Mountains were also mapped and 5 sheets of geological map series have been published by 1997. In addition to those terranes, a part of the Napier and Rayner Complexes in Enderby Land was also visited by the Japanese teams, and the Mt. Riiser-Larsen and Tonagh Island areas were mapped and published as well.

Through the geological investigations, the Lutzow-Holm Complex, the Yamato-Belgica Complex, the Sør-Rondane Mountains, the Napier Complex, and the Rayner Complex, have been characterized in terms of the lithology, metamorphic conditions and evolution, role of igneous activity, deformational history, and age datings, etc., to reveal the P-T-t-D trajectory for each complex. Such characterization is essential to consider the tectonic relationship among them and to discuss the geological correlation with the other terranes in East Antarctica. The geological, petrological, structural, and geochronological data were utilized not only to consider the evolution of East Antarctic continent but also for the correlation with other Gondwana fragments.

With respect to the geological correlation with Antarctica and Gondwana fragments, many Japanese Antarctic geologists have been conducting field surveys under international projects operated in such countries as Sri Lanka, India, South Africa, and Madagascar since late 1980s. The main object of these projects were not only to apply the jigsaw puzzle pieces to reunite the reasonable Gondwana, but also to trace geodynamic processes on continental evolution such as collision, break-up, etc. on a global scale.

Through the course of these Gondwana studies, we encountered some interesting evidence and issues related to challenging problems of petrology. They are;
➢ Charnockite in the making - What is the mechanism to generate incipient charnockite in biotite/hornblende gneisses? Any constraints as to the occurrence and distribution of such charnockite?
➢ Identification of tiny rapid-cooled felsite-nanogranite inclusions in garnet in UHT metamorphic rocks - What do those inclusions tell us about the lower crustal processes? Why have they cooled rapidly after the high-temperature conditions?
➢ Adakitic magma genesis and TTG formation – What is the mechanism of slab melting as a source for continental crusts?

These issues are all from micro-scale observations on rocks derived from the macro-scale Gondwana

research. However, the challenges of these themes may lead us to a new insight into future geological sciences.

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Context of the Ellsworth Mountains within East Antarctica and relationship with Laurentia

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The Ellsworth-Whitmore Mountains crustal block of West Antarctica is a critical element in any reconstruction of the palaeo-Pacific margin of Gondwana between Africa and East Antarctica. Current palaeogeographic reconstructions of the southern palaeo-Pacific margin of Gondwana place the Ellsworth-Whitmore Mountains block in a position between South Africa and Antarctica, but as part of West Gondwana. This is based on a similar rift setting during the Cambrian in the southern African, Falkland/Malvinas Islands and the Ellsworth Mountains. However, new U-Pb zircon dating of a micro-diorite gives an igneous crystallization age of 682 ± 10 Ma. These zircons have positive initial εHf and mantle-like δ18O values that indicate that rifting, which affected Mesoproterozoic crust, likely occurred in the Cryogenian. This strongly supports a connection of the Ellsworth-Whitmore Mountain block with East Antarctica before the amalgamation of Gondwana and agrees with the break-up of Rodinia in the context of the southwest United States and East Antarctica configuration. O and Hf isotopic compositions of detrital zircons from the Ellsworth Mountains also support this connection, indicating a likely East Antarctica provenance. A Cambrian magmatic event is recorded by zircons from a basaltic andesite dated at 518 ± 6 Ma. This magmatism is also related to an extensional setting, but one that is different from the Cryogenian micro-diorite. The Cambrian zircons have elevated δ18O values ranging from 7.59 to 9.07‰, indicating a strong sedimentary influence on the magma source, and crustal recycling. We interpret this Cambrian magmatism as a result of a tectonic escape after collision of the Australo-Antarctic plate with the West Gondwana/Indo-Antarctic plate.

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Ediacaran-Cambrian orogenesis in Gondwana – where were the Pan-African mountains?

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The East African Orogen and its inferred extension into Antarctica is a collisional orogenic belt that formed at 650–500 Ma during the assembly of the Gondwana supercontinent. Despite early suggestions that there is no detrital record of major orogenic events at this time, a period commonly referred to as the "Pan-African", it is now widely believed that the East African Orogen marks the former site of one Earth's most substantial mountain chains. These so-called super-mountains shed unprecedented volumes of sediment into fan systems that spread across Gondwana, and were associated with profound changes in Earth's surface environment including a rise in atmospheric oxygen and the first appearance of animals on Earth. However, this orogen is only one of a network of Pan-African metamorphic belts exposed across the southern continents and inferred under the Antarctic ice sheet, many of which are assumed to be collisional in origin and therefore also candidates for the location of the Pan-African super-mountains. Cambro-Ordovician sedimentary sequences eroded from these inferred super-mountains all have the characteristic "Gondwana age signature" of detrital zircon populations dominated by ~650–500 Ma (Pan-African) grains, with a secondary population of ~1200–1000 Ma (Grenvillian) grains, and various older grains. However, a comparison of published hafnium isotope compositions in these zircons reveals subtle yet important differences between those grains deposited across northern Gondwana (North Africa and the Middle East) and those deposited along the southern margin of Gondwana (eastern Australia, Antarctica, South Africa). Firstly, Pan-African grains in the north extend to more positive epsilon Hf(t) values, indicating a greater influence of juvenile Neoproterozoic crust in their source region and suggesting a link to the East African Orogen, while those deposited in the south extend to slightly younger ages (minimum ages of ~500 Ma) than those in the north (minimum ages of ~550 Ma). Secondly, Grenvillian populations have dominantly positive epsilon Hf(t) values in southern sedimentary sequences indicating a relatively juvenile late Mesoproterozoic source, but can extend to markedly negative epsilon Hf(t) values in the north. These latter differences can in turn be matched with contrasting Grenvillian-aged basement terranes reworked within the Gondwana network of Pan-African orogens, and in particular they link the southern detritus to a belt of Grenvillian arc terranes exposed in southern Africa, Sri Lanka and Dronning Maud Land of Antarctica, and inferred from geophysics to extend for some distance under the Antarctica ice sheet. These detrital signatures point to the locations of the major Pan-African mountain chains, with important implications both for the collisions that led to Gondwana assembly and the sediment transport directions and distances away from these orogens.

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The History and Tectonic Framework of Antarctica, Some Knowledge from the Subglacial Geology: A review

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Antarctica is known as an ice and snow world. Exposed bedrocks account for only ~0.3% of the total area. Although the exposed bedrocks are crucial for the geology of Antarctica, the information from beneath Antarctic ice sheet can provide irreplaceable knowledge for our understanding of the history and tectonic framework of Antarctica. In this presentation we review our investigation of glacial erratics in the Prydz belt, the northern Prince Charles Mountains as well as the Windmill Islands, Wilkes Land Coast and the Inexpressible Island, Northern Victoria Land since 2006/2007 season. 3-D S-velocity model for the Antarctic lithosphere, subglacial landscapes and regional Ice flow velocities were also combined to expound the early history of Antarctica and the key tectonic framework which formed the East Antarctic Craton.

Our investigation of glacial erratics around the eastern and southern Vestfold Hills, especially in the Sørsdal Glacier, southeastern Vestfold Hills demonstrates that there should be an Archean sub-glacier terrane near the Vestfold Hills and the Rauer Islands regions, with a Paleo-Archaean nuclei, which documented that the beginning of the geological history known for Antarctica could be traced back at least up to 3.5G. The glacial erratics and detritus yielded zircon U-Pb ages at 3530±8 Ma for a phyllite and those from 3350 ± 6 Ma, 3380 ± 18 Ma, c. 2800 Ma to a little over 2500Ma for quartzites, greenschists, phyllites and metamorphic trondhjemite clasts, which could be a provenance for the eastern Rauer Group high-grade metasedimentary rocks with Archean components. Two metamorphic trondhjemite clasts have prismatic igneous zircons and yield concordia cyrstalization ages of 3350 ± 6 Ma and 3380 ± 18 Ma, respectively. The εHf(t) values for the zircons of the trondhjemite clasts are predominantly negative although a few low negative values; and the two-stage Hf model (TDM2) ages of the zircons from the trondhjemite are between 3.6–4.2 Ga, demonstrating the trondhjemite having been derived from the remelting of older crustal protoliths. The Ar-Ar dating analyses on their amphiboles defined Pan-African ages of 585 ± 5 Ma and 522 ± 3 Ma for the two samples, and reflecting the Pan-African (i.e., latest Neoproterozoic to Cambrian) thermal event.

The Grove Mountains, ~400km south of Prydz Bay, were not significantly affected by a Grenvillian orogenesis, but represent a terrane that experienced Pan-African granulite facies metamorphism. The erratic rocks of high-pressure (HP) mafic granulite and HP pelitic granulite from the glacial moraines of the Grove Mountains were distinguished. They yielded peak metamorphism ages at 545±6Ma-542±6 Ma and 541±6Ma-540±7Ma respectively. Petrographical textures, mineral compositions and P–T pseudosection calculations in the system NCFMASHTO suggest that the HP mafic granulites record peak P–T conditions of 11.8–14.0 kbar and 770–840 °C, while those mineral assemblages of HP pelitic granulites and their P-T estimates based on the P-T pseudosection constructed in MnNCKFMASHT system define a clockwise P-T path involving metamorphic peak of 11.6 – 13.6 kbar at 817–834°C followed by a near-isothermal decompression of 6.7 – 7.5 kbar at 806–828°C, subsequent retrograde reactions involving near-isothermal decompression at ca. 530Ma to ca. 506Ma. HP mafic granulites and pelitic granulites from the Grove Mountains provide evidence for a collisional tectonic setting of the Prydz orogenic belt, which extends from the Prydz Bay to

southern Grove Subglacial Highlands, and then into inland Antarctica, the Gamburtsev Subglacial Mountains. It is this main suture that finally assembled East Antarctica Craton in latest Neoproterozoic to Cambrian.

Session05: The Neoproterozoic to Cambrian Orogenies and their precursors in Antarctica and adjacent continental blocks

New geochemical data from central Dronning Maud Land: Implications for Gondwana reconstruction.

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The western Mühlig Hoffman Mountains and the area around Gelsvikfjella in central Dronning Maud Land, East Antarctica can provide important information to the understanding of the assembly of the Gondwana Supercontinent. Rocks in this area comprise a polyphase deformed and metamorphosed assembly of Mesoproterozoic ortho-gneisses with minor supracrustal components and mafic bodies which were reworked during the late Neo-Proterozoic East-African Orogen and subsequent Kuunga Orogen and intruded by large volumes of post tectonic A-type granites of Cambrian age. In addition, the area has been intruded by multiple phases of syn- to post-tectonic leucocratic felsic veins which remained poorly studied until now. This study aims to provide a comprehensive geochemical survey of all rock types in the area but in particular the leucocratic felsic veins through the analysis (major, trace, REE and Nd-Sr isotopes) of 68 samples. The majority of basement rocks plots in the monzogranite – granodiorite field with the mafic rocks classifying as syeno- monzo-grabbro and gabbro. All the felsic veins (27 samples) plot as granite, however based on REE spider-diagrams the rocks are subdivided into two geochemically distinct groups. This distinction is supported by structural field data and cross-cutting field relationships. The distinction is furthermore supported by different isotopic signatures suggesting two different sources which are compared with basement gneiss signatures. The new geochemical data sheds light into the petrogenisis of the late felsic veins which could play an important role in the understanding of the final stages of collision in the Gelsvikfjella and Muhlig-Hoffman mountains where current theories are inconsistent and conflicting.

A053

Session06: Antarctic geothermal heat flux

Crustal heat production and terrestrial heat flow in central East Antarctica, with implications for thermal input to the East Antarctic ice sheet

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Terrestrial heat flow is a critical first-order factor governing the thermal condition and, therefore, mechanical stability of Antarctic ice sheets, yet heat flow across Antarctica is poorly known. Estimates of heat flow in East Antarctica come from inversion of seismic and magnetic geophysical data, by modeling temperature profiles in ice boreholes, and by calculation from heat production values obtained from exposed bedrock. Although accurate estimates of surface heat flow are critical for ice-sheet growth and stability models, there are no direct measurements of terrestrial heat flow in East Antarctica coupled to either subglacial sediment or bedrock. As has been done with bedrock exposed along coastal margins and in rare inland outcrops, valuable estimates of heat flow in central East Antarctica can be extrapolated from heat production determined by the geochemical composition of glacial rock clasts eroded from the continental interior. U, Th and K concentrations in a suite of Proterozoic (1.2-2.0 Ga) granitoids sourced within the Byrd and Nimrod glacial drainages of central East Antarctica indicate average upper crustal heat production (Ho) of about 2.6 ± 1.9 μW m-3. Assuming typical mantle and lower crustal heat flux for stable continental shields, and a representative distribution of heat production in the upper crust, the heat production values determined for individual samples yield estimates of surface heat flow (qo) ranging from 33-84 mW m-2 and an average of 48.0 ± 13.6 mW m-2. These results are in line with recent heat flow models for East Antarctica derived from upper mantle temperatures inverted from both S-wave velocities and aeromagnetic estimates of the Curie isotherm, which indicate craton-wide geothermal heat flux of ≤65 mW m-2 and lower values of 47-55 mW m-2 in areas like Dome A. Estimates of heat production obtained for this suite of glacially-sourced granitoids therefore indicate that the interior of the East Antarctic ice sheet is underlain in part by Proterozoic continental lithosphere with average surface heat flow, providing constraints on both geodynamic history and ice-sheet stability. More specifically, the glacial erratics were eroded and transported from a catchment that extends from the Byrd Glacier outlet of the Transantarctic Mountains up to the southwestern flank of the Gamburtsev Subglacial Mountains, indicating relatively low geothermal heat flux in an area critical for tectonic assembly and ancient paleoclimate records in old ice. The ages and geothermal characteristics of the granites indicate that crust in central East Antarctica resembles that in the Proterozoic Arunta and Tenant Creek inliers of Australia, but is dissimilar to other areas like the Central Australian Heat Flow Province that are characterized by anomalously high heat flow. Age variation within the sample suite indicates that central East Antarctic lithosphere is heterogeneous, yet the average heat production and heat flow of four age subgroups cluster around the group mean, indicating minor variation in thermal contribution to the overlying ice sheet from upper crustal heat production. Despite these minor differences, ice-sheet models may favor a geologically realistic input of crustal heat flow represented by such a distribution of ages and geothermal characteristics.

A075

Session06: Antarctic geothermal heat flux

Bed diagnosis in the Dome Fuji region, East Antarctica, using airborne radar data and englacial attenuation estimates

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Radar reflectivity of the ice-sheet bed has been used as a diagnostic measure of the basal conditions. Such bed diagnosis could lead to constrain magnitude and spatial pattern of geothermal flux which remains poorly known under the Antarctic Ice Sheet. Radar reflectivity can be estimated from the radar-observed bed returned power by extracting englacial attenuation. Attenuation exponentially depends on ice temperature, and can vary larger than the difference in the bed reflectivity for thawed and frozen beds. In the 2016-17 austral summer, Alfred Wegener Institute carried out 150-MHz airborne radar survey for ~19,000 line kilometers in a 400-km by 400-km area including Dome Fuji, East Antarctica, where the Oldest Ice is predicted to present. Bed topography, roughness, and subglacial hydraulic potential were analyzed and subglacial lakes were preliminary mapped. We extend that study by rigorous analysis of bed returned power. We hypothesize that model-predicted thawed area is consistent with high bed reflectivity area derived from the radar data, when englacial attenuation/temperature is derived for the correct geothermal flux. We carried out attenuation and radar reflectivity estimates for a range of geothermal flux and mapped spatial variations in the attenuation and bed reflectivity.

A082

Session06: Antarctic geothermal heat flux

Linking Antarctic geological observations and geophysical data in a probabilistic space.

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To understand the development of the Antarctic continent, and study properties of its crust and lithosphere, we have access to mainly sparse geological observations and extensive, but low-resolution, geophysical data. Early models are often based on only one or a few datasets, and interpretations can be non-unique. With a multivariate and stochastic model, we can better constrain ambiguities and depict interpretations of the Antarctic crust and lithosphere robustly and in a repeatable, shareable, way.

Recently, a number of improved geophysical datasets have been published. Data includes gravity acceleration from satellites, airborne measurements of the magnetic field, and maps of subglacial topography. Seismic models of the crust and lithosphere have also been refined, with new data and improved processing methods. Similar progress is seen in geological studies: new geological data have been acquired, and older data are reviewed and compiled. Observations from outcrops have been extended by marine core data and studies of glacial erratics to suggest properties of the subglacial terranes. Interpretations are supported by tectonic reconstructions of the East Antarctic continental margin.

We present an example of Antarctic basement/lithospheric terranes interpreted by linking geological observations with geophysical data utilising a probabilistic and multidimensional grid model. We use these domains to generate subglacial heat flow maps of the catchment area of the Aurora Basin for wider interdisciplinary use. The models are based on age-constrained crustal heat production, and we also include thermal properties from observations in adjoint Gondwanan margins, where available. We populate the domains with properties as age and provenance from geological data and use geophysics to extrapolate domain boundaries into the Antarctic interior.

The probabilistic approach illustrated in this presentation provides a robust and repeatable workflow. Our results and process are shareable with the broader community to use for interdisciplinary studies, and as a platform that will allow ongoing refinement.

A216

Session06: Antarctic geothermal heat flux

Geothermal heat flow and its influence at the base of polar ice sheets

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Future sea-level change primarily depends on the amount of ice mass loss in polar regions, which, in turn, depends on the conditions at the base of ice sheets. The thermal conditions are important because of widespread water beneath Greenland and Antarctica, affecting both ice-dynamics and mass budget. Melting or freezing at the base of ice sheets depends on the heat balance. This includes geothermal heat flow (one of the least known parameters affecting ice sheets), heat conducted or advected through the ice sheet, latent heat, and friction heat at the rock-ice interface. Here, the most advance models of geothermal heat flow derived using magnetic anomaly data are presented for Greenland and Antarctica, together with a discussion of the thermal conditions at the base of polar ice sheets. For Greenland, radar bed-echoes are discussed to better understand the basal water distribution of the ice-sheet and the relation to geothermal heat flow. For Antarctica, basal temperatures and melt rates are discussed to understand the influence of geothermal heat flow on these crucial thermal conditions.

A265

Session06: Antarctic geothermal heat flux

Estimating geothermal heat flux from ice sheet borehole temperature measurements

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Antarctic-wide estimates of geothermal heat flux are derived from models based on indirect observations of basal geology from global seismic models or satellite magnetic surveys of the continent. There are few direct measurements to verify these model estimates of geothermal heat flux. Here we describe two methods of discrete single point measurements of sub-glacial geothermal heat flux derived from direct borehole temperature measurements in the ice sheet. In one method, the borehole reaches the base of the ice sheet, and temperature measurement is available through the full ice thickness using discrete thermistors. Basal temperature is thus measured directly, and the geothermal heat flux is estimated from the thermal gradient near the base of the ice, and separately by solving the heat transport equation in ice by inverse methods. We demonstrate the resulting estimates of geothermal heat flux at four sites surrounding the Weddell Sea/Ronne Ice Shelf region. In the second method, the borehole penetrates only 20% of the ice sheet, but a combination of precise measurement of temperature from a Distributed Temperature System and discrete thermistors, together with englacial vertical ice velocity from phase-sensitive radio echo sounding allows us to estimate geothermal heat flux with a precision of 0.5 mW m-2. We validate this method with direct measurements of temperature from a borehole that does reach the base of the ice sheet, and show the estimate of geothermal heat flux at three East Antarctic sites, including the candidate site for the European project BeyondEPICA that hopes to recover the oldest ice core.

A357

Session06: Antarctic geothermal heat flux

A seismologically determined geothermal heat flux map of Antarctica

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The Geothermal heat flux (GHF) of Antarctica is an important boundary condition for modeling the movement of the dynamic ice-sheet, but is difficult to systematically measure in a remote and ice-covered environment. Indirect methods using geomagnetic and seismological methods have produced maps that suffer from low resolution and assumptions about tectonic activity, as well as crustal heat generation, which introduces large uncertainty. Here we combine the latest seismic models of Antarctica and relate them to the better measured GHF in the continental US through a seismic structure similarity functional, to produce a local GHF distribution for each locality of the Antarctic continent. From the local GHF distribution, we use the mean values to determine a new GHF map and use the standard deviation to define the uncertainties. We show that the new GHF map has improved resolution and lower uncertainties compared with earlier seismologically derived maps. It does not require ad-hoc assumptions in the tectonic setting as needed by the geomagnetic method and is consistent with most of the independent local measurements.

The new GHF map confirms the West-East dichotomy in Antarctica shown by earlier maps: relatively higher GHF (>60 mW/m2) is found in areas of Mesozoic and Cenozoic activity in West Antarctica and lower GHF (80 mW/m2) in the Thwaites Glacier region consistent with earlier radar-derived result, and 2) high GHF (>75 mW/m2) throughout the southern Transantarctic Mountains in the vicinity of the Titan Dome and Hercules Dome, co-located with the sub-ice lakes. However, unlike some earlier estimates, the results indicate there are no large-scale regions with heat flux greater than 90 mW/m2. We attribute the Thwaites high GHF to the thin lithosphere, and attribute the STAM high GHF to the warmer uppermost mantle introduced by lithospheric delamination reported earlier. We also note that the GHF estimate provides sufficient heat flux for the existence of most sub-ice lakes in Antarctica.

A413

Session06: Antarctic geothermal heat flux

Prominent mantle transition zone thinning beneath the Central Transantarctic Mountains

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The tectonic history of the Transantarctic Mountains, the mechanism promoting uplift, and the source for volcanism throughout Northern Victoria Land and the West Antarctic Rift is uncertain. Though a mantle plume has been proposed in the past to explain some of the volcanism in the Northern Transantarctic Mountains, tomographic images from this region have called this into question, as low-seismic velocity anomalies could be equally explained by vertical smearing of upper mantle low-velocity structures1,2. In addition, prior P-receiver function (PRF) studies found no evidence for a thinned mantle transition zone (MTZ), indicative of excess heat, immediately beneath the Erebus hotspot3. With the increase in broadband seismic instrumentation throughout Antarctica, we are able to detect MTZ discontinuities underlying larger portions of the Transantarctic Mountains and East Antarctica. We searched for anomalous features at MTZ depths by calculating more than 12,500 PRFs using the iterative time-domain deconvolution method4. We then migrated and stacked all PRFs using a 1-D global average velocity model. Following this, we corrected and re-stacked all PRFs using a 3-D global tomographic model5 overlain by a detailed Antarctic crustal model6. Where seismometers were located sufficiently close to each other, so that incoming seismic energy overlapped at MTZ depths, we stacked PRFs using a common conversion point approach. Our results reveal a zone of thinner than average MTZ (~200-220 km) beneath the Central Transantarctic Mountains (CTAMs). Grid south of this region, directly beneath the Erebus hotspot, our results concur with prior studies suggesting no MTZ thinning3. The MTZ anomaly beneath the CTAMs is also laterally offset from the grid north section of the Transantarctic Mountains, where prior tomographic images suggest the region is experiencing lithospheric foundering7. Taken together, we propose that a mantle plume is rising through the MTZ beneath the CTAMs and that, at upper mantle depths, it spreads laterally to other regions of the Transantarctic Mountains.

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2 Hansen et al. (2014), Earth Planet. Sci. Lett., 408, 66-78.
3 Reusch et al. (2008), Geophys. Res. Lett., 35, L12301.
4 Ligorría and Ammon (1999), Bull. Seism. Soc. America, 89(5), 1395-1400.
5 Simmons et al (2010), GyPSuM: J. Geophys. Res., 115.
6 An et al. (2015), J. Geophys. Res., 120.
7 Shen et al. (2018), Geology, 46(1), 71-74.

A420

Session06: Antarctic geothermal heat flux

Testing the hotspot hypothesis for Marie Byrd Land, West Antarctica using ice penetrating radar

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Evidence for active subglacial volcanism and high geothermal flux has been documented throughout the West Antarctic Rift System. Anomalously high geothermal flux (~114 mW/m2 on average) has been estimated in the Thwaites Glacier catchment using airborne radar based techniques, consistently with direct point measurements at WAIS Divide (~240 mW/m2) and Subglacial Lake Whillans drilling sites (285 ± 80 mW/m2).

Receiver function model results have also revealed thinned crust and a significant mantel velocity anomaly beneath volcano Mount Sidney, in the Executive Committee Range (ECR) in MBL. Subglacial volcanic activity had been previously documented ~50 km south of volcano Mount Sidley, where a swarm of deep long-period (DLP) earthquakes was registered in 2010 and 2011 by the POLENET seismic network. The DLP swarm was sourced ~25 km below a subglacial topographic and magnetic high, as shown by an airborne profile collected during the first season of the Geophysical Investigation of Marie Byrd Land (GIMBLE) project, located ~ 5 km to the east of the swarm center, and by aeromagnetic data from the earlier Airborne Geophysical Survey of Amundsen Embayment project (AGASEA). MBL was further surveyed as part of the second season of GIMBLE (2014-2015), during which airborne profiles were flown directly above the DLP swarm center to collect airborne data over the hypothesized subglacial volcanic edifice.

A version of the ISSM ice sheet model was recently utilized to investigate the effect on geothermal flux distribution consistent with a hotspot located at the DLP swarm center. The model used the distribution of active subglacial lakes as proxy for melt water (from which geothermal flux is inferred) and interpreted the absence of active subglacial lakes in the region as evidence for no excess geothermal flux. However, active lakes are one of two geophysical expressions of subglacial lakes, which can otherwise be detected in radar sounding profiles as hydraulically flat and radar reflective region.

Here we use both AGASEA and GIMBLE radar data to detect basal water in MBL, using a combination of specularity and bed echo data, adjusted using a spatially varying ice attenuation correction. Using water routing models, we infer the distribution of basal melt. We then compare the distribution of radar-detected basal melt with predictions of melt water rates produced by the published mantle plume parameterization in ECR. We show the melt water distribution observed from radar matches that predicted from the model thus supporting the hypothesis of a hot spot under ECR.

A456

Session06: Antarctic geothermal heat flux

Antarctic Geothermal Heat Flux: Past, Present and Future perspectives

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Geothermal Heat Flux (GHF) measurements and estimates of GHF via geophysical and thermal modelling are required to better predict past, present and future Antarctic ice sheet behaviour, including its dynamic responses to ocean and climate warming. In addition to its relevance for modelling subglacial hydrology and ice sheet dynamics, including e.g. the onset and maintenance of enhanced glacial flow, GHF serves as a boundary condition for paleotopography and paleoclimate studies (in particular for deep ice core drilling site selection), and is also important as both an indicator and an influence on the tectono-thermal evolution of the lithosphere.

Despite its pivotal importance, there is still a paucity of direct Antarctic GHF measurements. Consequently, geophysical estimates derived from seismology, satellite-magnetic and aeromagnetic data, and sparse MT, provide in many regions the only available constraints on the potential degree of spatial variability in GHF for much of the continent. In spite of some commonality, there are major differences in the currently available geophysical estimates of GHF, and this adds uncertainty to coupled ice sheet and Solid Earth studies (including GIA), as well as hampering our understanding of the Antarctic lithosphere and its tectono-thermal evolution. For example, some models predict high GHF in the interior of the West Antarctic Rift System (WARS), beneath parts of the West Antarctic Ice Sheet, while others favour instead higher GHF beneath the Marie Byrd Land dome (where a potential hot spot is located) and along the western edge of the WARS and beneath some parts of the Transantarctic Mountains front (where lithosphere delamination may also have occurred).

Reconciling these differences is imperative if we are to understand the tectono-thermal processes that affected the WARS and ultimately its current state, and subsequently assess its influence on several highly dynamic and potentially unstable sectors of the WAIS, including in particular the Amundsen Sea Embayment. Equally important, is getting a better handle on the regional and more local-scale variability with respect to the generally lower background values of the composite East Antarctic craton. This includes assessing intra-crustal GHF variations linked to its different cratons and orogenic belts and their overlying basins (e.g. Wilkes, Aurora, Recovery and Pensacola-Pole basins) that have recently received heightened international attention because of their influence on the stability of the East Antarctic Ice Sheet.

Here we present an overview that includes selected advancements in international Antarctic GHF studies, based on new lithospheric-scale modelling of ESA GOCE satellite-gravity data and the SMOS satellite mission, new models derived from seismology, different depth to Curie isotherm studies from terrestrial and satellite magnetic data, and heat production measurements from rock outcrops and glacial erratics, an example of anomalous englacial layer modelling to derive local GHF estimates, and the potential for new thermal isostasy studies as another proxy to derive large-scale Antarctic GHF variations.

We conclude that, in addition to more direct measurements of GHF and heat production from rock outcrops and erratics, community-based and more-fully integrated (adjoint) probabilistic modelling efforts, capable of assimilating these different data types and contrasting model outputs are likely to represent key requirements to improve upon currently available Antarctic GHF estimates. Successful examples of such community based international Antarctic geoscience initiatives exist (e.g. BEDMAP, ADMAP, AntGG). A new international and interdisciplinary open-science GHF initiative would have the potential to strengthen better joined up future lithosphere and cryosphere polar research.

Session07: Circum-Antarctic Gateways: formation, evolution and global implications

The final subduction of the Phoenix plate beneath the Antarctic Peninsula: A prelude to the opening of the deep Drake Passage oceanic gateway

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In this presentation we report our new results from recent years' investigation of the northern Antarctic Peninsula, the South Shetland Islands, especially the Smith Island aiming to reveal the history prior to the opening of the deep Drake Passage oceanic gateway.
The Smith Island is located just nearby the southeast end of the Hero fracture zone where it meets the South Shetland trench at its southwest. Parallel to which the South Shetland Islands was a late Mesozoic to earlier Cenozoic volcanic arc in which the King George Island, an earlier Cenozoic volcanic arc was their youngest segment along the eastern South Shetland trench. During later Paleocene to earlier Eocene widespread dioritic–granodioritic rocks were emplaced at ca. 62–54 Ma in the Booth Is, Doumer Is, Jougla Point, Antarctic Peninsula with a complicated deep process and the rift basin formed in the Andean Cordillera of Tierra del Fuego heralding the start of a new tectonic regime.
A combined petrological and geochronological study was carried out on very low-grade blueschists from Smith Island, South Shetland Islands, West Antarctica. The blueschists exhibit a similar mineral assemblage composed of sodic, sodic-calcic and calcic amphibole, chlorite, phengite, epidote, albite, quartz, calcite and sphene. Textures and chemistry of amphibole indicate three-stage metamorphic evolution from prograde blueschist facies, through peak blueschist facies, to retrograde greenschist facies. Pseudosection calculations in the model system NCKFMASHTO (Na2O–CaO– K2O–FeO– MgO–Al2O3– SiO2–H2O– TiO2–Fe2O3) yield P–T conditions of 330–350°C and 7.5–8.5 kbar for peak blueschist facies stage and 330–350°C and 3–4 kbar for greenschist facies stage. Therefore, a western Alpine-type clockwise P–T path involving post-peak near-isothermal decompression is deduced for the blueschists. 40Ar/39Ar dating of phengite and sodic amphibole yields well defined ages at 65±0.2 Ma to 62.2±0.2 Ma which reveals high-pressure metamorphism on Smith Island occurred in the earliest Paleocene. These data suggest that the Smith blueschists were buried to depths of ~25–30 km along a cold geothermal gradient of ~12–13 °C/km, and then rapidly exhumed by ~15 km during the earlier Paleocene subduction of the Phoenix plate beneath the Antarctic Peninsula. The rapid exhumation of the blueschists is attributed to the sharp slowdown of the latest subduction of the Phoenix plate and then the onset of development of the Hero fracture zone, a prelude to the opening of the deep Drake Passage oceanic gateway.

A202

Session07: Circum-Antarctic Gateways: formation, evolution and global implications

Modelling with high-resolution bathymetry demonstrates tectonic gateway induced cooling of Antarctica

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Declining atmospheric CO2 concentrations and tectonic opening of the Southern Ocean gateways have both been proposed to be the primary driver for the Cenozoic "Greenhouse-Icehouse" transition (~65 to 34 million years ago), one of the most fundamental global climate changes known in the geological history. More recently, the tectonic gateways hypothesis has been pushed into the background, because ocean models could not reproduce the expected "Greenhouse" conditions where heat was transported across latitudes from equatorial regions to the Antarctic coast.

Here we revisit this problem with a high-resolution general circulation model (MITgcm) incorporating a detailed Southern Ocean paleo bathymetry and constant atmospheric CO2 concentration. The bathymetric grid reconstructed to 38 Ma is built on sediment thickness data derived from seismo-stratigraphic and drill hole information, and preserves a more realistic seafloor roughness. We simulate changes in ocean circulation caused by stepwise subsidence of the Tasmanian Gateway and Drake Passage (300 m, 600 m, 1000/1500 m depths). The model is forced with stationary winds and thermal relaxation, and is spun up for 80 years. The results show that not one, but both gateways need to be sufficiently deep (> 600 m), in order for a significant ACC-type circulation to develop in the Southern Ocean. If at least one gateway is shallower, large-scale clockwise gyres dominate the Pacific and Atlantic Southern oceans. These gyres transport warm subtropical waters along their respective eastern boundaries towards the Antarctic coast, resulting in sea surface temperatures (SST) up to 18 °C. If one gateway is deep and the other one subsides below 300 m, the gyres are weaker and the SSTs are reduced by over 6 °C along most parts of the Antarctic coast. Once both gateways are deeper than 600m, a strong circumpolar flow dominates. The relative SST changes observed in the model correlate with results from paleotemperature proxies across the Eocene/Oligocene transition, derived from drill cores in the Southern Ocean.

Our model results differ significantly from previous ocean simulations, which emphasizes the importance of running models at higher resolutions and incorporating detailed paleo-bathymetric grids with more realistic seafloor roughness, similar to today's bathymetry. In these simulations, both gateways need to have deepened to significantly influence Southern Ocean SSTs and play a fundamental role in the Earth's transition into the modern "Icehouse" world.

Session07: Circum-Antarctic Gateways: formation, evolution and global implications

The South Orkney Microcontinent: an open door in the Weddell Sea mirroring the Cenozoic climate and tectonic impact of the opening of Drake Passage

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During the Eocene-Oligocene transition (EOT, ~34 Ma), Earth's climate significantly cooled along with the development of the Antarctic ice sheet. The timing and climatic impact of the opening of the Drake Passage on global climate remain controversial. Previous works suggest that, in the northwestern Weddell Sea sector, the initial deepening of the seaway at the late Eocene-Oligocene led to the isolation of the South Orkney Microcontinent (SOM) from the Antarctic Peninsula. Ocean Drilling Program (ODP) Site 696 in the southeastern margin of the SOM is a unique sedimentary record spanning the EOT (~36.9-32.2 Ma [1, 2, 3]) on which we have performed sediment facies, mineralogical, and geochemical (TOC, TN, C/N ratio, δ13C, δ15N, and n-alkanes concentration and distributions) analyses, to reconstruct the evolution of the SOM across this key interval. We first identified four sediment phases throughout the EOT, connected to the clockwise separation of the SOM (i.e., opening and subsequent deepening) from the Antarctic Peninsula. Phase I (~36.9-35.5 Ma) is characterized by a thick terrigenous sequence deposited at shallow-water (nearshore) depths under reduced-oxygen/salinity and temperate conditions, while the SOM was still attached to Antarctica. Phase II (~35.5 Ma) is marked by continuous deepening recorded by the onset of major green-clay (glaucony) authigenesis, attesting a sharp change in the SOM characterized by low sedimentation rates and sub-oxic, partially reducing conditions. We interpret this Phase in the SOM to record a major tectonic event mirroring an incipient proto-Powell rifting phase, as well as the development and strengthening of the ocean circulation in the northern Weddell Sea. Phase III (~34.1-33.6 Ma) corresponds to a continuous deepening of the SOM with a regressive event preserved in between. Further sediment characterization will allow elucidate if the regressive sediments result from continental ice sheet built up or local tectonic controls. Phase IV (~33.6-33.2 Ma) documents further deepening to bathyal depths punctuated by ocean stratification leading to dysoxic conditions. These conditions were paralleled by an increasing dominance of organic matter (OM) of marine origin over a terrestrial one in our sediments. It can be explained first by the establishment of a change in the water mass circulation stimulating surface phytoplankton productivity at the newly formed oceanic Powell basin. Secondly, our terrestrial biomarkers exhibit a shift from relatively humid temperate forest to a dry and cool forest, which implies a weaker contribution of the terrestrial OM to the marine sediments. These cooling conditions detected on land are found to be synchronous with the development of illite minerals and major ice-rafted debris deposition, suggesting the appearance of sea ice and icebergs regionally. While iceberg traces were detected in the northern Weddell Sea by late Eocene times [4], our study only evidences a climatic deterioration after ~33.6 Ma. Likewise, and on the basis of dinoflagellate cyst records, Houben et al. [2] documented sea ice conditions only until after earliest Oligocene (~33.6 Ma). Although the different steps in the Drake Passage opening remain unclear, our sediment and geochemical records report a main tectonic change at ~35.5 Ma, and a major climate cooling between ~33.6 and 32.2 Ma most likely associated with the Drake passage deepening.

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Cenozoic magmatism along the Antarctic Peninsula: a new key to constrain Phoenix plate subduction and the development of the Scotia Arc

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The Antarctic Peninsula (AP) host a former magmatic arc that was formed due to the subduction of oceanic lithosphere of the Phoenix Plate under the continental lithosphere of the AP. This convergent margin took place since at least the Triassic. Later, during the Late Cretaceous-Neogene period, the subduction ceased progressively south to north by the collision of spreading ridge segments at the continent ocean boundary and finally the Antarctic-Phoenix spreading axis becomes inactive. Subduction now only continues at the northern tip, along the South Shetland trench, although is largely considered to be in a state of very low activity. The South Shetland Islands are separated from the Antarctic Peninsula by the development of the Bransfield Strait back-arc basin.

The cessation of the subduction in the AP is one of the most distinguishable features of the Cenozoic period in West Antarctica, connected with the opening of the Drake Passage during the development of the Scotia Arc. Geophysical studies have been used to suggest that the shot down occurred towards the Paleogene-Neogene boundary. However, there is rather scarce geochronological or geochemical control of this hypothesis, probably due to the scarce presence of outcrops of plutonic rocks of this age. Thus, key questions remains about the timing and geochemical evidence of this process, which could be better understood by the study of the last products of the subduction coupled with geophysical studies including gravimetric, magnetic and multichannel seismic researches.

We present a multidisciplinary study that involves a detailed characterization of the plutonic rocks located in the west coast of the AP. This dataset consist in: i) geochronology (U-Pb LA-ICP-MS in zircon and 40Ar/39Ar in groundmass), ii) isotopic tracing (Hf in zircons and Nd-Sr-Pb in whole rock), and iii) geochemical studies. The geochemical and geochronological data are complemented with geophysical studies on Antarctic Peninsula and the Scotia Arc that contribute to constrain the geodynamic evolution of the region.

LA-ICP-MS analyses of 9 granitoids yield U-Pb zircon concordant ages in the Paleogene and Neogene spanning between ca. 55 and 41 Ma, and between ca. 22 and 19 Ma, respectively. 40Ar/39Ar in groundmass and hornblende yielded weighted mean plateaus ages that span between ca. 28 and 19 Ma. This suggest presence of plutonics rocks produced in the last stages of the subduction. The emplacement of the Eocene magmatism appears to be in a constant, approximately stationary position at the west coast of AP. These ages are close to the early stages of development of the Scotia Arc evidenced by 42 to 43 Ma age of the oldest oceanic crust of the southern Scotia Sea. However, the Miocene plutonism seems to be displaced ~50km westwards. We suggest this shift is related to the rollback associated to the last stages of the subduction, provoking a westward migration of the arc. This setting is in agreement with the opening of the Bransfield Strait along the northern tip of the Antarctic Peninsula.

The literature has indicated that the isotopic compositions of the Antarctic Peninsula granitoids were formed as a result of subduction during the Mesozoic. Our data shows a progressive increase in the mantle sources that formed the magmas in the Paleogene, which continued through the Neogene. We suggest that this is in agreement with the westward migration of the arc due a rollback process. The trend towards a relative more isotopically juvenile compositions reflects the upwelling of the enriched mantle provoked by the slab window related to the rollback and cessation of the subduction. Moreover, the opening of the Drake Passage may also have favored the juvenile character of the magmas and contributed to the instauration of new mantle channels with the eastward inception of the Pacific mantle in the Scotia Arc.

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Early stages of oceanic spreading in the NE extremity of Antarctic Peninsula: relationships between Ona and Powell basins

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The opening of the Drake Passage, connecting Pacific and Atlantic oceans, was a main tectonic event that occurred during the Late Eocene-Early Oligocene impacting the global climate . The occurrence of this gateway was a consequence of the development of the Scotia Arc, where the former continental connection was dismembered, surrounded by small oceanic basins. The NE extremity of the Antarctic Peninsula and its prolongation along the continental crust of the South Scotia Ridge underwent an early stage of ENE-WSW extension, parallel to its main elongation. In its southern boundary opened of the Powell Basin during the relative northeastwards displacement of the South Orkney microcontinent. In its northern boundary developed a series of ENE-WSW extensional oceanic basins along the southern Scotia Sea: Ona, Protector, Dove and Scan basins. This early stage was followed by a second stage of NW-SE oceanic spreading in the Drake Passage related to the activity of the West Scotia ridge. Seafloor spreading magnetic anomalies contribute to discuss age and sequence of oceanic spreading in both sides of the South Scotia Ridge. Ona Basin constitutes the westernmost basin of southern Scotia Sea. Its western sector is characterized by with N120ºE linear magnetic anomalies with 80 to 170 nT amplitudes, suggesting that oceanic spreading started at Chron C16n.1r (35.892-36.051 Ma) and ceased in time of Chron C9r (27.439-27.859 Ma) with an average velocity of 0.8 cm/yr. Its eastern sector, in the boundary with the Terror Rise, N130ºE linear magnetic anomalies of 50 to 100 nT amplitude support that spreading process started near the time of Chron C20n (42.301-43.432 Ma) and ceased in time of Chron C18n.1r (39.627-39.698 Ma), with an average spreading velocity slower than 1.7 cm/ yr. To the other side of the South Scotia Ridge, Powell Basin is characterized by moderate to low amplitude magnetic anomalies (30 to a maximum of 300 nT), with a NNW-SSE spreading axis located in the middle of the basin, and covered by a thick sedimentary layer. Previous proposals suggest that the spreading occurred for 4 to 8 Ma in a range between 35 and 18 Ma. Considering our available data, spreading magnetic anomaly modelling suggests that spreading started at Chron C17n.3n (38.093-38.159 Ma) and stopped in time of Chron C11n.2n (29.527-29.9701 Ma). Spreading velocities varied from 0.6 up to 1.5 cm/yr, and were generally close to 1 cm/yr. Despite the limitations of the magnetic anomalies interpretations in small basins, due to short magnetic anomaly profiles, our data and the best fitted models improve the knowledge on the earliest stages of continental crustal stretching during the development of the Scotia Arc. The continental crust of the Antarctic peninsula and its prolongation along the South Scotia Ridge remained relatively more stable, including elongated batholiths of Cretaceous gabbro related to the PMA (Pacific Margin Anomaly). ENE-WSW stretching along the elongated piece of Antarctic Peninsula continental crust started in the north (42.301-43.432 Ma, western Ona Basin), and switched to the south (Powell Basin) during 38-39 Ma. Since 35-36 Ma stretching occurred in both sides of the South Scotia Ridge (western Ona and Powell basins) and finally ended at 27-29 Ma, when extension

migrated to other Scotia Arc basins. Our data provide new insights about the tectonic evolution during the early stages of Scotia Arc development.

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Decoding Cenozoic Tectonics in Patagonia, the Scotia Sea, and the Antarctic Peninsula from New Seismic Tomography

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The increase in Antarctic broadband seismic data over the last ~15 years combined with novel full-waveform adjoint tomography has not only enhanced shear wave speed images of the Antarctic upper mantle and transition zone, but has also improved images of other regions in the southern hemisphere. Here we examine a new tomographic model of the seismic structure of the far southern hemisphere (ANT-20; Lloyd et al., submitted 2019) to explore the shear wave speed structure beneath Patagonia, the Scotia Sea, and the Antarctic Peninsula, which reveals important constraints on the Cenozoic subduction history. Beneath Patagonia fast shear wave speeds of the subducted Nazca plate are observed north of the Nazca-Antarctic-South American triple junction, while south of this point average and slow shear wave speeds indicative of young oceanic lithosphere and a slab window are imaged. At deeper depths fast slab-like shear wave speeds are indicative of the older subducted Nazca plate. Within the Scotia Sea the currently subducting South American plate at the South Sandwich Trench is clearly imaged extending into the transition zone and very shallow slow shear wave speeds are observed beneath the adjacent East Scotia Sea back arc spreading center. Further to the west and within the transition zone fast shear wave speeds are found, which may be the remnants from an ancestral South Sandwich Subduction Zone [Dalziel et al., 2013; Pearce et al., 2013]. Finally, fast shear wave speeds are imaged beneath the northern part of the Antarctic Peninsula (near ~65°W) between 200 to 800 km depths. At shallower depths (< 200 km) in this region and to the south along the Bellingshausen Sea Coast slow shear wave speeds consistent with a slab window are observed. Intriguingly these shallow slow shear wave speeds continue east of ~65°W and underlie the Shetland Plate and the South Scotia Ridge.

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Commotion in the ocean revisited; putting tectonic gateways in their place

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To explain the sudden and widespread glaciation of Antarctica, Jim Kennett outlined the tectonic gateway hypothesis in a series of articles and monographs in the late 1970's. At the time, benthic oxygen isotope records were used to argue for the widespread glaciation of Antarctica during the middle Miocene, with the discovery of 'significant' decline in bottom water temperature close to the Eocene/Oligocene boundary. The opening history of Drake Passage—then considered to be the final barrier to complete circumpolar circulation—had been outlined in detail in the late 1970's. The coincidence of Drake Passage opening, and presumed onset of the Antarctic Circumpolar Current (ACC) in the Miocene, with Antarctic glaciation captured the attention of the geoscience community. Even as it was realized that the Eocene/Oligocene boundary represented the major development of Antarctic ice sheets, new reconstructions of Drake Passage were pushing the earliest opening back into the Oligocene and into the Eocene.

Testing the tectonic gateway hypothesis drove paleoceanography for many decades. These research activities produced important datasets used for paleoclimate reconstructions that have provided the rapidly evolving field of paleoclimate modeling with boundary condition parameters. Since the early 2000's a consensus view has evolved that places carbon dioxide levels in a more influential role for Antarctic glaciation, however the state of tectonic gateways remains an important parameter for paleoceanographic and paleoclimate reconstructions. In this talk I will examine the evolution of the circumpolar zone of low gradients in water mass tracer fields, which is one of the key features of the modern ACC. This important data set places important constraints on the state of tectonic gateways throughout the Cenozoic climate transition, but also has its limitations. Lastly, I will outline the important unanswered questions regarding gateways, circulation, and linkages to glaciation in the context of current and future drilling campaigns in the Antarctic Southern Ocean.

A038

Session08: Evolution of Antarctic topography and bathymetry: understanding links between erosion, deposition, isostasy and ice sheet behaviour

A spatial-statistical assessment of the likely detritus supply from past ice-sheet changes in Wilkes Land, East Antarctica.

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A key tool in understanding changes in past ice sheet extents is the use of detrital provenance methods, which may seek to determine the location of eroding zones indicative of the ice sheet state at particular times. Determination of source regions from detritus relies, firstly, on a sound knowledge of the subglacial geology, but also of a good understanding of the likely dynamics of the eroding ice sheet. Mixed signals, derived from multiple glaciers each sampling a varied geology, complicate matters greatly, and the need emerges to solve for multiple unknowns simultaneously. In addition, source and sink are separated by a transport pathway that is rarely known well. Here we consider the value of adding ice sheet models into the interpretation workflow, as a means to map quantitatively the generation of detritus by glacial erosion, and the likely "at source" provenance signal resulting. This study applied in Wilkes Land demonstrates a method by which to achieve this based on spatial statistics: The method requires a prior interpretation(s) of subglacial bedrock geology, and a suite of ice sheet models that indicate the erosion potential in differing model scenarios. Zonal statistics, applied within GIS, allows for the relative amounts and proportions of detrital material that can be expected from each geological unit to be defined for each ice sheet state. Differences in total erosion capacity can also be defined for different states, although a volumetric erosion estimate requires calibration to sedimentary deposition volumes. For the four ice sheet states we studied, substantial differences in "at-source" provenance are defined. This implies that, for this region, changes in ice sheet state are likely to generate detectable changes in the detrital provenance recorded. Furthermore, the observed detrital record can be more reliably traced back to the source regions, providing a firmer constraint on past erosion linked to particular ice sheet states. Uncertainties remain with respect to the accuracy of the ice sheet models; in transforming geological interpretations into the isotopic systems traced; and also in the transport pathways, the efficiency of which may vary substantially through time. Despite these, our analysis method provides a template for more robust linking of detrital provenance data to subglacial erosion, enabling better reconstruction of the evolution of the past ice sheet and its bed.

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Session08: Evolution of Antarctic topography and bathymetry: understanding links between erosion, deposition, isostasy and ice sheet behaviour

Reconstructions of Antarctic palaeotopography since the Eocene–Oligocene boundary and implications for ice sheet behaviour

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Antarctica's bedrock topography exerts a fundamental control on ice sheet behaviour, and has likely evolved significantly throughout its glacial history. Accurate models of past Antarctic ice sheets therefore require a realistic reconstruction of bedrock topography at the time interval of interest. Here, we present new reconstructions of Antarctic topography at four time slices: the Eocene–Oligocene boundary (ca. 34 Ma), the Oligocene–Miocene boundary (ca. 23 Ma), the mid-Miocene climatic optimum (ca. 14 Ma), and the mid-Pliocene warm period (ca. 3.5 Ma). To reconstruct past topography we consider a series of processes including ice sheet loading, volcanism, thermal subsidence, horizontal plate motion, erosion, sedimentation and isostatic adjustment, and constrain our models with onshore and offshore geological datasets.

Our reconstructions show that the land area of Antarctica situated above sea level was ~25% larger at the Eocene–Oligocene boundary than at the present-day. During the Oligocene and Miocene, deep near-coastal topographic troughs formed around the margin of East Antarctica, with up to 3 km of material removed by erosion, which in turn drove up to 1.5 km of flexural uplift of adjacent highlands. Contemporaneously, large areas of West Antarctica were experiencing thermal subsidence associated with the West Antarctic Rift System. By the mid-Miocene, the topography of East Antarctica began to closely resemble that of the present-day, and much of West Antarctica had subsided below sea level. Offshore sediment records and terrestrial constraints indicate that after the mid-Miocene, erosion and sedimentation rates in West Antarctica increased by ~50%, whereas rates in East Antarctica decreased by ~50%, with large areas experiencing relatively little modification after ca. 14 Ma.

We perform some simple ice sheet model sensitivity experiments using these new topographies, and find that the Antarctic Ice Sheet has become progressively more sensitive to climate and ocean forcing as a result of landscape evolution processes, particularly in the vicinity of deep near-coastal subglacial basins around the margin of East Antarctica. Our new palaeotopographies provide an important boundary condition for models seeking to understand past behaviour of the Antarctic Ice Sheet, and the implications for changes in global ice volume, temperature, and sea level across major climate transitions of the Cenozoic.

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Session08: Evolution of Antarctic topography and bathymetry: understanding links between erosion, deposition, isostasy and ice sheet behaviour

Bedmap3: the vision for a new ice thickness and subglacial topography dataset

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The aim of the Bedmap3 project is to produce a new map and datasets of ice thickness and bed topography for the international glaciology and geophysical community.
The previous iterations of Bedmap have been successful and widely used. Both the original Bedmap and Bedmap2 projects have published maps and databases of ice thickness and bed topography that have been extensively utilized by the international glaciology and geophysical community. Scientist from 36 institutions in 18 countries provided data for the Bedmap2 project and the output from the project has become one of the most cited Antarctic papers of the last decade.
Here we report on the plans and progress of the new Bedmap3 project. This project will run for three years and have a number of stages that will be supported by a specific SCAR Action Group. This talk will coincide with the open the call for ice thickness data from the international community and an invitation for data providers and users to become part of the Bedmap3 user group. We will highlight a number of known sources of recently collected RES and Seismic data and will propose a new multi-level data contract with data providers. We will discuss the proposed products of the project and the possible use of modelled data to add value to previous approaches. Finally, we will unveil plans for a new Bedmap3 interactive website and other mechanisms of data delivery and community projects.

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Four seasons' airborne survey in the Princess Elizabeth Land, the largest data gap of Antarctica

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Ice thickness, bedrock topography and subglacial conditions of the Princess Elizabeth Land (PEL) in central East Antarctic Ice Sheet (EAIS) are still unknown due to lack of direct geophysical measurements. This prevents our understanding of the ice sheet dynamics, subglacial morphology and climate evolution in the region. In fact, the PEL is the largest geophysical data gap in Antarctica. By analyzing surface landscape of the satellite data, a large, previously undiscovered subglacial lake and subglacial canyons and drainage networks were found may exist beneath the ice in PEL. The subglacial canyons may extend over a distance of ~1100 km from inland to coast. China deployed its first fixed-wing airplane named Snow Eagle 601 and implemented airborne geophysical investigation in PEL in 2015. Until now, four seasons' airborne surveying campaigns have been finished. The HiCARS deep ice-penetrating radar system, GT-2A gravimeter, CS-3 magnetometer, laser altimeter, GPS and camera are configured and integrated in the airplane to provide systematical measurements for both ice and continental bedrock. We have collected more than ~150000 kilometers flight lines data, and the data will contribute to our knowledge of ice sheet geometry, subglacial conditions and geology in the PEL, and help to understand the ice sheet change and potential influence to global sea level in future.

Session08: Evolution of Antarctic topography and bathymetry: understanding links between erosion, deposition, isostasy and ice sheet behaviour

A suite of paleobathymetric grids of the Cenozoic Southern Ocean - a key to understanding the interlinked evolution of ocean circulation patterns and the Antarctic ice sheets

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The Southern Ocean plays not only a fundamental role in today's ocean current system, but has been key in the establishment and development of the Antarctic ice sheets throughout the Cenozoic. By calculating new paleobathymetric grids, based on all available reflection seismic and borehole data for the Antarctic margin as well as its conjugate margins of Australia, New Zealand, South America and Africa, we present a more accurate geometry of the seafloor and its dynamics over long time scales. This not only enables the development of more sophisticated models of paleo-ocean circulation and the paleo-environment including paleo-ice sheets, but also allows us to observe the local and regional changes in the Southern Ocean since the Eocene/Oligocene boundary, revealing the step-wise development of ice-house conditions in the Southern Ocean realm as well as the reaction of specific regions to alterations in glacial, tectonic and atmospheric boundary conditions. The early opening of the Tasman Gateway and thus the establishment of a southern deep-water connection at ~30 Ma between the Indian Ocean and the Pacific signifies a key process towards today's ice-house world. Our paleobathymetric grids of different stages from the Eocene-Oligocene Boundary to the early Miocene allow us to investigate the fundamental changes in sedimentation patterns, which is closely linked to the evolution of the ocean current system. By transitioning from an isolated basin between Australia and East Antarctica to a deep-water exchange through the Tasman Gateway, we infer a unique setting of an early glaciated East Antarctic continent and an isolated Australian-Antarctic warm water pool at 34-30 Ma. This resulted in an immense increase in sedimentation rate in the deep sea. The massive sediment accumulation was decoupled from terrigenous supply and is thus potentially related to a high biogenic production.

After the establishment of the Antarctic Circumpolar Current (ACC) and the development of the Antarctic ice sheets, the regional sedimentation dynamics changed dramatically from a primarily re-deposition of sediments by ocean current transport in the deep sea prior to the Oligocene to an increased sedimentation by downslope processes related to massive glacially-driven transport across the shelves. This glacially dominated sedimentation mimics the overall dynamics of the Antarctic ice sheet ranging between intense periods of glaciation and deglaciation. A reduced ice sheet during the Mid-Miocene Climatic Optimum led to a decrease in terrigenous sediment transport to the continental shelves, especially in regions with low-lying paleotopography. Intensification of glaciation such as the growth of the ice sheets in the Late Miocene also show a strong regional connection between the continental topography and the sedimentation accumulation in the ocean, pointing to important aspects regarding the growth pattern of the Antarctic ice sheets as well as their stability and erosional capacity. Our paleobathymetric models document regional and local changes in the activity of ice streams enabling detailed regional analysis of, e.g., the see-saw switching between

neighboring major ice streams and the effect of regional paleotopographies.

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Session08: Evolution of Antarctic topography and bathymetry: understanding links between erosion, deposition, isostasy and ice sheet behaviour

Present-Day Land and Sea Level Changes around South Georgia Island: Results from Precise Levelling, GNSS, Tide Gauge and Satellite Altimetry Measurements

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South Georgia Island, the main land outcrop on the South Georgia microcontinent (SGM), is located approximately 1,400 km east of the Falkland Islands and approximately 1,400 km northeast of the northernmost tip of the Antarctic peninsular. The SGM is believed to lie south of the North Scotia Ridge (NSR), which forms the boundary to the South America Plate, while to the south it is bordered by the Scotia Plate (SP). In its sub-Antarctic location, the island is largely covered by mountain glaciers which have been reported to be retreating due to climatic change. Furthermore, during past glaciation periods the island and its shelf area, stretching much of the SGM, have been ice covered as was revealed by scarring of the sub-oceanic topography. Together with ongoing tectonics along the NSR and recent seismicity at the SP boundary, these processes have the ability to produce significant uplift on local to regional scales.

With its mid-ocean location in the Southern Atlantic Ocean South Georgia Island is in a key position for the oceanic and geodetic global monitoring networks. As these net-works suffer from a Hemisphere imbalance with the number of stations in the Northern Hemisphere outnumbering those in the Southern Hemisphere, operating these stations to the highest standards is of key scientific value. It is of particular interest to monitor the tide gauge (GLOSS ID 187) at King Edward Point (KEP) for vertical land movements to establish a continuous record of its datum within the Permanent Service for Mean Sea Level (PSMSL), which in turn makes it useful for long-term sea level studies and satellite altimetry calibrations.

With the establishment of five GNSS stations on the islands by teams from Luxembourg, the UK and the USA during 2013 to 2015, and the scientific analysis of these data within a global network of stations, it has now become possible to study present-day vertical land movements and their impacts. Furthermore, together with four precise levelling campaigns of the KEP benchmark network in 2013, 2014 and two in 2017, it has also been possible to investigate the very local character of the vertical motions near KEP, i.e. the stability of the jetty upon which the tide gauge is mounted. In this study, we will present the still preliminary results from the GNSS and levelling measurements and will discuss their impact on the sea level record from the KEP tide gauge. Our measurements show that while South Georgia Island and the area around KEP are rising, the jetty and tide gauge are subsiding, leading to a lower magnitude of the observed sea level change than expected from satellite altimetry. In order to improve the agreement between these measurements both local and regional vertical land movements need to be monitored.

Session08: Evolution of Antarctic topography and bathymetry: understanding links between erosion, deposition, isostasy and ice sheet behaviour

Geologic Structure of the Crary Ice Rise

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Ice rises that form within the interior of ice shelves provide significant buttressing to grounded ice. The Crary Ice Rise is located just downstream of the Whillans Ice Stream's grounding line. Previous work has demonstrated that the evolution of the Crary Ice Rise and the Whillans Ice Stream are linked. Thus, we conducted a geophysical experiment to understand the origin and evolution of the Crary Ice Rise. We collected 20 km of active source seismic data along two profiles, one parallel and one perpendicular to the main ridge of the ice rise. The seismic data reveal over 600 meters of sediments as well as complex structure present beneath the Crary Ice Rise. This indicates that the topographic high responsible for the ice rise is not due to an elevated region of exposed bedrock. Instead, it appears that the topographic high has been formed as the result of both the regions tectonic history and interactions with the overriding ice sheet. We are continuing to explore geodynamic implications for the observed geologic structures and their potential influence on ice sheet behavior. Understanding the interaction between a stagnating ice stream and an ice rise will improve interpretations of ice stream behavior over centennial time-scales.

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Session08: Evolution of Antarctic topography and bathymetry: understanding links between erosion, deposition, isostasy and ice sheet behaviour

Bathymetry and history of the Ross Ice Shelf

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A new, high-resolution bathymetry model of the Ross Ice Shelf reveals the connection between deeply incised bed beneath the grounded ice of the Siple Coast and the relatively smooth bathymetry of the Ross Sea. The ice sheet bed of the Siple Coast area of West Antarctica has been sounded with ice-penetrating radar, revealing elongate ridges and valleys with peak-to peak width of 10 km or greater and up to a kilometer of relief. In contrast, the bathymetry of the Ross Sea, mapped from acoustic sounding from ships shows a subdued topography, where thick sediments of the continental shelf mask the basement topography. Seafloor bathymetry varies from 10s to 100s of meters, on length scale ranging from 10s to 100 kilometers and reflecting the erosional and depositional history of recent glacial cycles.

Both regions lie below sea level, and are connected by the seafloor underlying the Ross Ice Shelf, which has previously been sounded only by sparsely (55 km) distributed seismic shot points of the 1970s RIGGS project. The ROSETTA-Ice project surveyed the Ross Ice Shelf at ~10 km resolution, including aerogravity measurements to reveal the bathymetry underlying the ice shelf. The new bathymetry model shows rougher topography than previously resolved, suggesting that the sub-ice shelf region is more similar to the Siple Coast than the Ross Sea.

ROSETTA-Ice results show the grounding line of both the East and West Antarctic sides of the Ross Ice Shelf to be deeper than previously known. Near the grounding zone of Kamb Ice Stream, 80 m relief, 100 km long and 50 km wide ridges approximately align with the orientation of present day ice flow, and may have served to channel ice flow in the past when the grounding line was more advanced.

The bathymetry under the ice shelf present a previously unknown boundary condition, influencing the present day circulation of seawater beneath the ice shelf as well as the flow of the ice when it was grounded in this region. Past interactions between the ice shelf and seafloor are suggested by the tracing of features within the ice shelf back along flow to high elevation points of the bathymetry model. Variations in the underlying geology of lithospheric strength will have further influenced grounded ice flow, through distribution of geothermal heat flux and a variable lithospheric response to unloading of ice on either side of the ice shelf.

A089

Session09: Permafrost and Periglacial ice free areas in Antarctica

Geomorphology and landscape vulnerability of the ice-free Vestfold Hills, East Antarctica

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Ice-free areas cover less than 1% of Antarctica and are the focus of human activity on the continent however there is little information on the vulnerability of surficial sediments to human impacts. We have undertaken detailed geomorphic mapping in the deglaciated Vestfold Hills, East Antarctica, to understand landscape evolution and provide a basis for future landscape vulnerability assessments and environmental management. We have used Visual Site Assessments and Structure from Motion photogrammetry to characterise the resilience and recovery of different landform and sediment types after impact. These techniques have also been employed in the McMurdo Dry Valleys, enabling comparisons between ice-free regions with different substrates and climates.

The Vestfold Hills is an ice-free region of ~400 km2 on the margin of Prydz Bay, East Antarctica. The landscape is dominated by outcropping crystalline basement (Archean to Paleoproterozoic granulite and gneisses) crosscut by mafic dykes. Overlying the bedrock, shallow valleys are filled with undulating, moderately-consolidated till and marine and aeolian deposits. The land surface is covered with boulders and gravel pavements, depressions, and salt crusts. Till veneers cover bedrock highs. Mounds and small hills consisting of poorly-consolidated till dominate the landscape in some areas. These form topography that is distinct from the largely bedrock-controlled highs. Marine sediments form benches along a valley-lake system, extending from near the modern coast to 15 km inland towards the ice sheet.

We hypothesise that the impact, recovery, and resilience to physical disturbance will differ between different landforms and sediment types. Visual Site Assessments (1-3) were used to evaluate disturbed sites against a range of visual criteria to assess impact and recovery. Structure from Motion photogrammetry (e.g. 4) was used to capture high-resolution imagery before and after disturbance to track recovery. Detailed imagery reveals that foot passes cause greater impact to finer-grained material than to coarse-grained sediment, with higher visual impact to marine sediments than till. This contrast is noticeable from as few as 20 foot passes.

Future work will involve assessing recovery over a longer period, investigating the physical and chemical properties of sediments, and undertaking further comparisons with other ice-free sites on the continent. This will contribute to our understanding of local-, regional-, and continental-scale variations in vulnerability to inform environmental management.

This study is part of Australian Antarctic Science Project 4393, Assessment of landscape vulnerability to human impacts in the Vestfold Hills, Prydz Bay, supported by the Australian Antarctic Division.

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A096

Session09: Permafrost and Periglacial ice free areas in Antarctica

Characterization of ornithogenic factor in soil-forming processes in Maritime Antarctica

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Antarctic soils are known as very diverse in morphology, chemistry, texture and mineralogical composition. Differences in geographical locations (by latitude) and existence of so-called Antarctic oases, which are isolated from each other by ice sheets and snow masses causes significant pedodiversity of Antarctic continent. In severe climatic conditions of Antarctica birds play an important role in transportation of organic matter to the coastal landscapes. This study is aimed to investigation of ornithogenic factor in soil formation on King George and Ardley islands. Our work revealed that redistribution of guano components affects significantly the speed of soil cover spatial development and formation of new polypedons of soils in environments of rookeries. Analysis of mesomorphological organization of soil aggregates showed different rates of association between guano remnants and mineral grains in humus horizons, which is caused by variability in both fine earth content and guano decomposition rate. In this study, 13C NMR Spectroscopy was performed to analyze soil organic matter of Ornithosols, Post-Ornithosols and Cryosols not affected by bird activity. We found that the humic acids (HAs) of the cryoturbated, buried areas had lower amounts of alkyl aromatic and protonized aromatic compounds. In contrast, the HAs from the surface layers contain less alkyl carbon components. Our data showed that the portion of aromatic compounds is little higher in soils under materials transported by birds compared to soils under mono species of bryophyta or lichens communities. This is probably caused by the fact that birds use mainly remnants of Deschampsia antarctica (which contains increased portion of phenyl-propanous organic precursors) for nest building. The free-radical content was higher in the surface layers than in the buried layers due to the presence of fresh organic remnants in superficial soil samples. Measurements of electrical resistivity of soil and permafrost strata were performed with a portable device LandMapper with vertical electrical resistivity sounding approach (VES).
Permafrost table depth in studied soils ranged from 89 to 100 cm. Cryoturbation process and supra-permafrost accumulation of moisture which are widespread in the studied soils, lead to cryogenic mass transfer, heterogeneity of soil mass, and complication of the profile distribution of electrical resistivity values. The character of parent material determines temperature and water regime in soil, rate of cryopedogenesis, dynamics and thickness of active layer and permafrost table. This study was supported by RFBR, grant 18-04-00900 "Ornithogenic soils of Antarctica: formation, geography, biogeochemistry and bioindication".

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Permafrost of Barton Peninsula: Surveys by Seismic Tomography, Active Surface Waves and Microtremors

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While glacial regions are distributed over ¼ of the terrestrial mass of the earth, permafrosts are the ones with the greatest ratio in this distribution. However, in many places where permafrosts are spread, especially in Antarctica, there are few scientific studies due to difficulties in terms of transportation and logistics. For this reason, the most of the scientific studies are based on remote sensing, surficial observation and measurements. These studies are not enough to understand the processes occurred into a complex structure such as permafrost, and make it necessary in-situ methods. Barton peninsula, where the King Sejong Station of Republic of Korea is located, one of the location permafrost could be seen. Barton Peninsula is generally covered with acid sulfite soils and andesitic basement. Here, this study presents the first results of the project which has been composed in order to image permafrost structures with high resolution and to be followed in different time periods (time-lapse monitoring) by multi-geophysical methods with an integrated approach. While the project includes seismic, electric and electromagnetic methods, the proposed study focuses on the seismic methods; seismic refraction (for first arrival tomography), active surface wave (for Rayleigh dispersion curve) and microtremors-ambient noise (for H/V). While active layer is seen in first 1-1.5 meters with 1000-1200 m/s for P-wave and approximately 700 m/s for S-wave, four main ice-rich structure appears under the active layer on district spatial locations with 3200-4200 m/s for P-wave, 2000 m/s for S-wave. It can be seen on S-wave velocity profile that a transition unit between base rock and ice-rich permafrost presences with 1400 m/s for S-wave, 5000 m/s for P-wave. Then, base rock is located approximately at 30 m with 3000 m/s for S-wave. Ambient noise measurements for 16 location mostly demonstrate stabile fundamental frequency as 7.42 Hz. Also, ocean wave effects are clearly seen on 30 Hz. As a result, seismic wave velocities demonstrate that the permafrost structure could be named as "discontinues permafrost" with thin active layer and large scale unfrozen zone. Fundamental frequency and S-wave velocity of deeper parts show that base rock could be characterized as highly stiff and massive. The next step of the proposed project is to create time-lapse section with more measurements on different time periods and following structural and geometrical changes of the permafrost. The project crew hopes to provide the data for different aspects of several researches such as global warming, climate change-cycling, e.t.c.

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Burial of cold-based glacier ice in the McMurdo Dry Valleys, Antarctica

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The McMurdo Dry Valleys are the largest region on the Antarctic continent that is not currently glaciated by the ice sheets. However, the Dry Valleys do contain ice, in the form of alpine and outlet glaciers, buried glacial ice, and interstitial ice in near-surface sediments. We investigated four ice-cored deposits in central Taylor and Pearse valleys. The goals were to (1) characterize the buried ice in terms of occurrence, thickness, stable isotope geochemistry, crystallography and gas inclusions, (2) analyze the sedimentology of overlying and englacial debris, and (3) refine depositional models for the burial of cold-based glacier ice in the relatively warm regions of the Dry Valleys.

All four ice-cored rock glaciers occur in the inland, low-elevation sector of the Dry Valleys, where summer air temperatures > 0º C for many weeks per year, the active layer is 30+ cm thick, and ephemeral meltwater streams are common. Ground-penetrating radar (GPR) imaging and shallow seismic surveys, indicate that all four landforms contain clean ice lenses 1–15 m thick. Buried ice occurrence is sporadic and ice often occurs within 50 cm of the ground surface (based on field excavations). Overlying sediments are predominantly fluvial, colluvial and eolian. Stable isotopic analyses (n=138) from 11 shallow ice cores extracted from the buried ice support glacial origins for the ice, with minor meltwater modification in the upper ~10 cm of some cores. All potential source glaciers are currently cold-based at the study locations.

We hypothesize two formational processes for the studied ice-cored rock glaciers: (1) deposition of lateral ice-cored drift and (2) accumulation of glacier ice aprons and sediments below bedrock slopes. Fluvial and colluvial deposition is key to ice burial in both cases, since cold-based glaciers lack significant englacial debris. Our analyses indicate that some ice-cored rock glaciers have complex formational histories, likely recording multiple advances of source glaciers, and in one case sourcing from both outlet and alpine glaciers. In addition to recording glacier fluctuations from late Pleistocene to Holocene time, ice-cored rock glaciers in Taylor and Pearse valleys could also help constrain the geomorphic conditions that result in stability vs. degradation of buried ice in cold deserts.

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Session09: Permafrost and Periglacial ice free areas in Antarctica

Dynamics of frost mounds and icing blisters in perennially frozen lake in continuous permafrost areas of continental Antarctica (Terra Nova Bay, 74° S)

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Frost mounds are widely distributed and studied in arctic and subarctic regions. In Antarctica the variety of frost mounds is reduced to small pingo-like features [1], icing blister [2] or debris cones [3] always associated to frozen lakes. The genesis of these Antarctic frost mounds is still under debate [1,2] and no studies focused on the dynamic of such landforms.

Here we present how the volume of 2 frost mounds (M1 and M2) changes during several years in a perennially frozen lake in Terra Nova Bay (74° S, continental Antarctica).

Previous (since 1996) aerial and terrestrial images of other Antarctic expeditions were used for a visual estimation of the mounds changes. Moreover, in November 2017 and 2018, 2 helicopter surveys were used to take overlapping pictures of the frozen lake with a close circular flight. In addition, for a furtherly better definition of surficial changes, 2 drone photogrammetric surveys were conducted at the beginning and end of December 2018. The digital elevation models (DEMs) and orthophotos of the lake were obtained in Agisoft Photoscan, while the spatial and temporal analyses on the DEMs were conducted in ArcGIS 10.3. Field measurements of surficial snow/ice sublimation on the lake surface were carried out through an installation of 40 white plastic tubes (40 cm long, 1.5 cm diameter) inserted vertically at 15 cm below the surface and distributed on the lake statistically representing the different surface types. 4 measures of the above-surface length of each tube were recorded with a ruler every 10 days from 11-11-2018 to 16-01-2019.

Analyzing 3 longitudinal height profiles crossing through the frost mounds, it is clear that the external border of the lake is stable and a vertical accretion of 10 and 11 cm was measured at the top of M1 and M2 respectively. The volumetric accretion of the mounds apexes resulted in +0.55 m3 for M1 and +0.31 m3 for M2. These results suggest a larger variation of M1 during the last year, while the interannual variability observed through visual analysis of older pictures demonstrates a much higher variability of M2.

The whole summer water balance of the lake is negative with a higher sublimation at ice/snow surfaces (2.4 cm), followed by snow surfaces (2 cm) and then by ice surfaces (0.7 cm). Considering the difference between the two high-resolution DEMs related only to December 2018, an average accumulation of 3.6 cm for ice, 14.9 cm for snow and 8.7 cm for ice/snow surfaces was found.
In conclusion, the summer water balance of the lake was negative but the two mounds have an opposite trend with an accretion of 10 and 11 cm respectively. Moreover, the accretion of ice on the lake surface during December indicates a probable hydraulic recharge through an open-system talik

as demonstrated by the occurrence of intra-permafrost brines [2].

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A case study of vegetation variation in permafrost using Geophysical methods near the King-Sejong Station

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Electrical resistivity tomography (ERT) and ground penetrating radar (GPR) mapping are representative methods for investigating the shallow subsurface structures. According to the previous permafrost studies, electrical resistivities and dielectric constants are crucially affected by the amount of water present in the active layer.
Very important parameters of electrode configuration and interval of the ERT are chosen for the research to test their suitability especially in the mapping the shallow zone within 2 m depth. The GPR method are used to delineate the boundary between the active layer and the permafrost, furthermore to find out the time-varying permafrost depth.
The purpose of this study was to attempt to correlate the results from the geophysical data acquired in the melting season with the ones from the vegetation data collected in the Barton Peninsula of the King Sejong Station in Antarctica. The ERT measurements were made using a four probe Wenner array with 64 channels of 1 m electrode spacing. 500 MHz antenna was used for GPR survey. The vegetation of the study area is classified into three types, and the three types are examined from a geological point of view. In order to confirm the properties of the active layer and the depth of permafrost layer interpreted from the geophysical data, we examined the water contents and the electrical conductivities of 80 cm-deep pit excavated at four anomalous points in the geophysical data.
Regarding the data collected in the total length of 40 m, it appears that vegetations of Sanionia(moss), Ochrolechia(lichen), and Usnea(lichen) predominate at the spreads of 0-21 m, 22-29 m, and 30-40 m, respectively. ERT and GPR data indicated high water content and deep active layer in the Sanionia-rich region, Toward the Usnea-rich region, on the contrary, water content is decreasing and the active layer is thinning.
The ERT data showed a low resistivity band and the strong reflection signal was measured in the GPR data. As a result of digging of the land, a black clay layer about 5 cm thick appeared at a depth of about 60 cm. It is presumed that the waterway, which is now located at 13 m on the profile, was located at 28 m in the past.

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Session09: Permafrost and Periglacial ice free areas in Antarctica

Genetic particularities of rock glaciers and protalus lobes in James Ross Island, Antarctic Peninsula

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Rock glaciers and protalus lobes are considered common landforms in the non-glaciated areas of James Ross Island (northern Antarctic Peninsula). The formation and dynamics of these landforms are related to morphostructural and morphogenetic environmental conditions, being the most important the presence of basaltic mesas that provide the raw material for the debris cover of the rock glaciers and protalus lobes.

In the case of rock glaciers, the morphogenetic conditions involve small polythermal glaciers that due to little summer temperature variations, subtle reduction in the precipitations, and/or changes in the intensity and direction of the main regional winds, become debris covered. An important factor related to the debris cover, particularly to the nearly homogenous debris distribution over the whole glacier surface, is related to the so-called oscillation of the regelation front.

Under stable climatic conditions, after the debris cover reaches a thickness similar to that of the active layer, the ice core ablation diminishes markedly, remaining only the own plastic deformation of the ice core. The debris cover of the rock glaciers studied in James Ross Island reaches around 0.3 m in thickness close to the valley head, increasing the thickness to more than 1 m in the fronts. The ice cores rarely exceed 80 m in thickness.

The flow velocity of some of these rock glaciers have been monitored since 1992, using total station and differential GPS to measure marked boulders. The results show that the average flow velocity is 13 cm/year. In addition, the temperature of air and soil at different depths has been monitored showing that the mean annual air temperature is around -6.2°C.

Unlike the tongue-shaped rock glacier protalus lobes seem to develop without direct relation to glaciers. The environment required for their formation comprises steep talus slopes, enough debris supply, and the presence of perennial or late-lying snow patches. Most of the frost-shattered materials are removed from the outcrops by rock slide, roll and fall and transported on the talus slope by frost creep, gelifluction, snow-debris avalanches, debris slide and flow, etc. Debris, snow, later transformed into interstitial ice, provide the physical conditions for protalus lobes flow activity. At the foot of a meseta near the Whisky Bay a protalus lobe affected by thermal erosion and mass wasting was discovered, allowing description of the internal structure of this landform. The 30 m outcrop show a succession of up to 3 m thick pure ice layers interbedded with up to 2 m ice immersed or cemented debris layers. The important ice content together with the debris load promote strain and creep of this landform.

The severe climatic warming verified in the last decades in the northern sector of Antarctic Peninsula accelerated the collapse of both of these landforms. This is evident in the formation of ponds on the surface and thermal erosion at the steep marginal slopes as well as changes in flow velocity.

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Session09: Permafrost and Periglacial ice free areas in Antarctica

Thermal regime of the active layer and permafrost below the Machu Picchu Peruvian station (Antarctic Peninsula): Preliminary results

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The Scientific Station Antarctica Machu Picchu is open only in summer and is located in Punta Crepin, Admiralty Bay, King George Island, Antarctic Peninsula. The main module and the shelter, built in 1989, are infrastructures that are above the surface through metal pillars (0.2 to 0.95 m approximately separated from the surface), a space that is covered preferably of snow during the winter. In the summer, these structures maintain a different microclimate abroad both in the environment as in the subsoil, (less affected by the maximum and minimum temperatures), producing a conservation of low temperatures at depth. Soils where accentuate the structures, are composed of marine deposits sandy gravels (with little matrix) highly permeable. These conditions, are the ones that would have resulted in the creation of permafrost under the main module and the refuge, which was registered during the excavations of maintenance of the station in February 2018. In that same month in 2018, we made two holes under the main module, 9 sensors were installed below the surface and 7 sensors between the surface and the station distributed in PERM01 and PERM02 (Ng et al, 2018). During the excavations, frozen ground are 0.5 and 0.62 cm under the ground in PERM01 and PERM02 respectively. The distribution of sensors in PERM01 sensors were installed at 0.2, 0.4, 0.6, and 0.8 m above the surface, and at 0.15, 0.4, 0.5 and 0.6 m under the ground; and PERM02 sensors were installed at 0.2, 0.4 and 0.6 m above the surface, and at 0.15, 0.4, 0.52, 0.62, and 0.72 m under the ground. In this summary, it performs a comparison of subsurface thermal variation in relation to the microclimate produced in the temperature of the air under the station, according to Guglielmin et al. (2008). The frequency of data collection was every 30 minutes, however for the processing we used hourly recordings. The sensors employees were HOBO model 002-064, with accuracy of 0.53 °C and resolution of 0.14 °C; it also installed a temperature sensor of the same series to 1.70 m above the surface, within a protector of radiation outside the station (BAP01-AMB). The period of data assessed was 17-02-18 to 07-01-19 (325 days) for all sensors, however three sensors are partial data: PERM01+060 until 05-12-18 (290 days), PERM02+040 until 26-12-18 (313 days) and in PERM02-052 until 12-11-18 (269 days). To compare the temperatures of the subsoil, complete the data of PERM02-052 with isothermal days (sensors above and below this depth also recorded isothermal days). To get an idea of variation of soil temperature in the deepest sensors, it is also compared data from PERM01-050 and PERM02-052, and PERM01-060 and PERM02-062 because of its minimal separation in depth (2 cm). At each station, the temperature increases with respect to the height of the sensor (despite the fact that the difference is 20 cm per sensor). There is a difference between the air temperatures to 20, 40 and 60 cm in terms of altitude, being higher toward the stop at each point. There is also a difference of the air temperature at 20, 40 and 60 cm above the surface, between the two seasons: PERM01 is more susceptible to temperature changes from the outside, arriving to have negative and positive values in the peaks during the year. It is also noted that the hourly data show an effect of zero curtain in PERM01, which is more stable while you are closer to the surface. To 20 cm from the surface, the effect curtain in PERM01 is of 4 November to 12 December 2018. There appears to be an increasing number of isothermal days (170 to 142, 210 to 183 and 221 to 191 days) to 15, 40 and 50 cm depth; and fewer freeze-thaw days (42 to 76, 25 to 76, 19 to 84 and 20 to 48 days) to 15, 40, 50 and 60 cm depth; in PERM02. On the last thawed day (> 0.5 °C) in subsoil is the 01-04-18, and do

not return to register. Subsurface temperatures between 0.5 and -0.5 °C remain uninterrupted from the 11-08-18 until the end of the readings.

A059

Session10: Modern landscape change in Antarctic ice-free areas

Moisture after midnight: Inferred widespread soil salt deliquescence in McMurdo Dry Valleys soils during late-night relative humidity peaks

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Water is a limiting factor in cold desert landscape evolution in Antarctica, and acts as a throttle on soil biogeochemical processes such as chemical weathering and clay formation, carbon mineralization, and solute transport. Most soils in the McMurdo Dry Valleys (MDV) of southern Victoria Land are extremely dry (2000 mg cm-2. In some MDV soils, the presence of highly deliquescent soil salts such as antarcticite and/or perchlorate compounds leads to the formation of isolated "wet patches"—2-3 meter diameter dark patches of nearly perennially damp soil (~3% water content by mass) caused by absorption of atmospheric humidity into concentrated, low-water activity solutions. Previously, these "wet patches" were thought to be spatially isolated and to represent an unusual soil hydrogeological process occurring in locations of anomalous salt concentrations, compared to regionally-extensive glacier runoff and groundwater flow through water tracks from snow melt.

Here we investigate field reports of widespread soil darkening during periods of high relative humidity in Taylor Valley and the surrounding MDV (Lake Bonney and Spaulding Pond basins). During periods of high humidity, valley scale (kilometer length scales) darkening of the soil surface has been reported in the absence of snow melt. These anecdotal reports suggest that these widespread soil dampening events occur when solar elevation is lower than the height of the valley walls, resulting in rapid cooling of the soil surface and the atmospheric boundary layer.

We investigate the hypothesis that during periods of high relative humidity, some soils in the MDV undergo soil salt deliquescence and brine growth leading to wetting and darkening of the soil surface. We analyzed relative humidity and soil reflectivity measurements made at McMurdo Dry Valleys Long Term Ecological Research (MCM-LTER) weather stations from 1995 to 2018. RH measurements were made 3 m above the soil surface. Reflectivity measurements are a ratio of upwelling shortwave radiation to downwelling shortwave radiation made using a pair of Eppley pyranometers (295-2800 nm). Data were analyzed from eight stations for the month of January during the hours 00:00 to 02:00 local time, when all stations received no direct solar radiation.

We find a strong correlation between soil reflectivity and overlying air relative humidity at the Lake Bonney and Lake Vanda stations, with possible detections of RH-associated soil darkening at Lake Vida. Darkening correlated with high RH values is not observed at the other stations.

Darkening is observed when RH exceeds ~40-60%, resulting in a decrease in reflectivity of ~33%. Based on hyperspectral measurements of experimentally wetted MDV soils, these reductions in reflectivity are consistent with growth of soil moisture contents from 0 to ~2 wt.%., or more than double baseline soil moisture contents.

We interpret these measurements to indicate that deliquescence of soil salts is occurring in response to high RH conditions, leading to growth of saline solutions in the intergranular pore space of soils in the Bonney and Vanda basins. These basins have notably higher soil salt concentrations than more

coastal MDV sites, which may not have developed the requisite salt density needed to produce visibly wetted soils in response to high RH conditions.

We infer that these changes to apparent reflectivity do not result from observational effects for two reasons: 1) observations are only reported during times when the stations receive no direct illumination (00:00 to 02:00 local time), and 2) reflectivity does not correlate with day of month. That is, there is no systematic change in reflectivity over time/zenith angle.

Session10: Modern landscape change in Antarctic ice-free areas

Holocene stream degradation of pre-Holocene buried ice in the Dry Valleys: using optically stimulated luminescence dating of fluvial deposits

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Buried ice and rock glaciers are common throughout the McMurdo Dry Valleys, Antarctica. We studied seven rock glaciers (defined here as flowing ice-rich or ice-cored sediments) in central Wright, central Taylor and Pearse valleys. Analytical methods included ground-penetrating radar (GPR) imaging of the subsurface, stable isotopic and major ion geochemistry of clean buried ice, and optically stimulated luminescence (OSL) dating of near-surface sediments. The goal of these analyses were to constrain (1) the presence of clean ice at depth, (2) the age and origin of ice deposition / rock glacier formation, and (3) the modern degradational processes, if present.

Here we focus on one ice-cored rock glacier in Pearse Valley and two ice-rich rock glaciers in the North and South Forks of Wright Valley. The GPR data indicate little to no clean ice in the South Fork rock glacier, supporting a talus-derived origin for this landform. Preliminary OSL dating of stratified near-surface sediments (n=11) on the Wright Valley rock glaciers yield depositional ages from Holocene (< 10 ka) to late Pleistocene (100–200 ka). Conversely, the northern Pearse rock glacier is cored by clean ice lenses up to 14 m thick, overlain by poorly to moderately stratified sands and gravels. Stable isotopic data (n=67) from five cores support a glacial origin for the buried ice, sourced from both the local alpine glaciers and Taylor Glacier, an outlet of the East Antarctic Ice Sheet. The last mapped advance of Taylor Glacier that was sufficient to reach the rock glacier (~200–250 m above the modern margin) occurred during Marine Isotope Stage 5 (70–125 ka). Preliminary OSL dating of sediments that stratigraphically overlie the buried ice in Pearse Valley (n=3) also support a pre-Holocene age for the rock glacier, with depositional ages of ~13–80 ka. Despite the antiquity of this landform, all of the OSL samples (n=15) associated with stream dissection of the buried ice and fan deposition distal to the rock glacier yielded Holocene depositional ages; most of these samples (n=12) date to < 6 ka.

These data indicate that (1) initial rock glacier formation and buried ice deposition in Pearse and Wright valleys likely pre-dates the Holocene (possibly MIS 5 or older), and (2) that increased Holocene stream activity is causing degradation of ice-cored rock glaciers by incision and exposure of the ice. After buried ice is exposed in stream channel banks, especially after high stream years such as 2001–2, it can rapidly melt back. Stream activity on talus-derived rock glaciers in Wright Valley exhibits a complex relationship with subsurface ice, both eroding channels and acting as a source of sediments and ice to the rock glaciers.

Session10: Modern landscape change in Antarctic ice-free areas

Too cold, too dry and no dust: McMurdo Dry Valleys, Antarctica

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Dust sourced from high latitudes is increasingly recognized as an important component of the global dust budget. Although only comprising about 5% of global dust, it may have a disproportionately large environmental impact as a source of nutrients to polar marine and terrestrial ecosystems. In Alaska, Iceland, and Patagonia, where water and glaciofluvial processes are abundant, large volumes of dust are known to be produced and transported via atmospheric suspension for thousands of kilometers (Bullard et al 2016).

The McMurdo Dry Valleys (MDV) are the largest ice-free area in Antarctica and therefore potentially a major source of dust for the Ross Sea and beyond. However, our analysis suggests that despite the strong foehn winds and abundance of sand (>60 microns), rarely does dust.

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Pre-middle Miocene landslide deposits in the central Transantarctic Mountains

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Landslide deposits, a consequence of load exceeding rock strength in over-steepened topography, include stratigraphically coherent blocks of strata up to several hundred meters in strike length and scores of meters in thickness, which may travel kilometers from their points of origin. In some cases, movement is facilitated by water lubrication on the surface of failure, but more far-travelled deposits may ride on air cushions.

The central Transantarctic Mountains has several examples of coherent blocks close to their sources, but the most spectacular are separated by kilometers. Most of these are in positions incompatible with emplacement on present-day topography. In one instance, at Buttress Peak, a coherent block of Jurassic Kirkpatrick Basalt, with a stratigraphic thickness of about 245 m and a 40° dip, overlies horizontal Triassic Falla Formation basal sandstones. The block, on its north flank, abuts a 300 m high cliff of in situ Falla strata, and lies 6 km north of the nearest in situ basalt. A Jurassic sill intruded into underlying strata and lacking offset precludes an origin by crustal tectonism. Prior to emplacement, erosion must have formed mesa topography with at least 1,000 m of relief. Around 15 kilometers north, near Mt. Falla and on the shoulder of a ridge, a rotated block of Kirkpatrick Basalt lavas, with a stratigraphic thickness of 150+ m, overlies Triassic upper Falla Formation beds. About 45 kilometers farther north, a series of ridge-capping Permian and Triassic blocks, as much as 12 km from their bedrock sources on Mt. Mackellar, overlie basal sandstones of the Permian Buckley Formation at and south of Mt Fairchild, and indicate erosion of 2,500+ m of strata before deposition.

Present climate precludes recent movement along slip surfaces lubricated by water. With the projected minimal rates of uplift since mid-Miocene times (< 1 m/m.y.), and the high present-day elevations of these landslide blocks (> 2000 m), emplacement probably occurred in the more distant past. The relationships of the landslide blocks to present-day topography suggest that there were several episodes of landslide formation and that significant mesa topography had developed before block displacement. This most likely occurred much earlier than the Miocene, possibly in the Eocene before the onset of the first major Antarctic glaciation and early in the uplift history. New techniques for dating and modelling applied to these deposits might usefully contribute to the early uplift history of the central Transantarctic Mountains.

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Spatio-temporal variability of Antarctic tafoni. Are thermal events directly responsible for cavernous weathering?

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Cavernous weathering, also known as tafoni, occur in arid, coastal and Antarctic environments mainly on granitic lithologies. Several processes are thought to be involved in their formation such as: temperature fluctuations, salt weathering, wetting and drying cycles [1], lichens bioturbation [2]. Among all, the temperature temporal and spatial variability in tafoni could be treated as the principal driver of other processes, especially in Antarctica [3, 4]. Due to the complex morphology of tafoni, it is difficult to set up a well-distributed network of thermistors. For this reason, infrared thermography (IRT) could help in quantifying the spatial variability of the surface temperature [5].

In this study the spatial variability of surface temperatures was monitored through IRT for all the summer season on the main morphological sectors of 4 tafoni: floor (F), internal side (S), ceiling (C), top (T). In order to understand the role played by the thermal spatial variability on the weathering of the caves also measurements of weathering susceptibility were carried out.

The tafoni were chosen at Oasi near Mario Zucchelli Station (Terra Nova Bay, 74° S, continental Antarctica), all westward oriented but with different morphometry of the caves. Since 10-11-2018 one thermistor (0.2 °C of accuracy) per each sector of tafone was installed at 2 cm of depth. Each sensor recorded until 29-01-2019 every 1 minute. During the same period, a total of 18 thermal images (FLIR E85, 384 x 288 pixels, 2 °C accuracy) were taken to include: (a) the possible largest area for each sector (spatial variability) and (b) the thermistor location (area adjacent to the thermistor and 10 cm of ray) (temporal variability). Subsequently, seasonal minimum, maximum, mean and range were computed for (a); daily mean, median, amplitude, standard deviation and different thermal indices (like thermal amplitude (AMP), freezing-thawing cycles (FTC) at 0 (FTC0) and -1.6 °C (FTC1.6), thermal shocks (TS) within 1 (TS1) and 2 °C (TS2) per minute) were computed for (b).

Linear regressions between thermistors data and the (b) images showed good results ($R2 > 0.74$ and $p < 0.001$).

Generally, thermal ranges (a) were higher on (T) and (F) except for one case on (S). Differently, thermal amplitudes (b) were relatively higher on (C) and (T) except for one case on (S). Moreover, FTC (FTC0 > FTC1.6) were much more abundant than the almost absent TS (TS1 > TS2) except for one case on (T) and one on (C).

Despite their similar aspect, the different morphometry leads a great intra-cave spatial variability but also large differences among sectors of different tafoni. Generally, (T) and (F) of all tafoni showed the largest temperature ranges due to the more direct and continuous influence of the incoming radiation. Thermal amplitudes, instead, were noticeable on (C) and (T) of all tafoni likely due to the major role played by the sensible heat compared to solar radiation. However, we cannot directly associate the higher frequency of thermal events and thermal ranges/amplitudes with disintegration of granite. Indeed, the largest weathering susceptibility was recorded at (S) and (C) of all tafoni, indicating that other processes prevail in the development of these landforms.

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A050

Session11: Applied bathymetry for understanding Quaternary history and change

Topographic and substrate control on active icesheet retreat during the Late Holocene, offshore Windmill Islands, Antarctica

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Understanding ice sheet history provides important constraints for modelling ice sheet response to changing climate. High resolution (1m) multibeam bathymetry from the nearshore region of the Windmill Islands, East Antarctica, records a detailed history of active retreat followed by stagnation, related to Late Holocene expansion of the Law Dome ice sheet. The seafloor data reveal discrete areas of exposed, heavily fractured crystalline bedrock incised by a network of subglacial meltwater channels. The highly fractured bedrock, coupled with a stable subglacial drainage system, would have promoted the removal of meltwater from the ice-bed interface resulting in reduced basal sliding, leading to static or slow moving ice; a conclusion supported by the lack of streamlined features preserved on the bedrock surface.

The offshore region is also dissected by a series of narrow, fault-controlled channels and wider embayments that abut 40–60 m high bedrock escarpments. These topographic features were likely floored by marine sediments which had a profound effect on ice sheet dynamics during retreat, reflected in the landform record preserved on the seafloor. A series of arcuate or hairpin-like recessional push-moraines (2–25 m high) are confined within the channels, transitioning to more rectilinear landforms where the channels widen into embayments. The form of the moraines provides a detailed record of the changing ice margin shape during retreat, switching from laterally continuous features, indicative of a broad continuous ice margin, to distinctly hairpin-like or saw-tooth landforms with marked crevasse squeeze ridges at their terminations. These more complex landforms record the development of an irregular, highly fractured ice sheet margin with large open longitudinal crevasses separating finger-like pecten of ice. Crevasse squeeze ridges are most common adjacent to the escarpments, indicative of the lateral shearing of the retreating ice against the escarpment wall. Cross-cutting relationships displayed by individual moraine ridges, in particular immediately adjacent to the escarpments, record a complex pattern of active ice sheet retreat with recession punctuated by phases of readvance. This complex pattern of retreat is believed to reflect the presence of a soft deformable bed beneath the ice within the fault-controlled channels and embayments, promoting greater forward movement of the ice during readvance. By contrast, in areas with a hard bed composed of potentially free-draining, highly fractured bedrock the retreating ice mass was slow moving or even static, despite external drivers that resulted in periodic surging of other parts of the ice sheet during the overall deglaciation of the Windmill Islands.

This high-resolution dataset provides new understanding of the dynamic retreat of the East Antarctic ice margin. The style of retreat revealed is similar to active valley glacier systems today, and had not previously been anticipated from the seemingly stable East Antarctic ice sheet. This dataset underpins the value of mapping the Antarctic seafloor at high resolution with multibeam sonar and applying the data to ice sheet reconstructions. This work was undertaken as part of a collaborative program with the Royal Australian Navy and the Australian Antarctic Division to map and understand nearshore Antarctic environments.

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Session11: Applied bathymetry for understanding Quaternary history and change

Past and future dynamics of the Brunt Ice Shelf from seabed bathymetry, ice shelf geometry, and instrumental data

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The rapid growth of rifts in the Brunt Ice Shelf is contributing to the development of its largest calving event since records began in 1915. We carried out a study to determine whether this calving event will lead to a new steady state, in which the Brunt Ice Shelf remains in contact with the bed, or an unpinning from the bed, which could predispose it to accelerated flow or possible break-up.

We used a range of geophysical data to reconstruct the sea-floor bathymetry and ice shelf geometry, to examine past ice sheet configurations in the Brunt Basin, and to define the present-day geometry of the contact between the Brunt Ice Shelf and the bed. Results show that during past ice advances grounded ice streams likely converged in the Brunt Basin from the south and east. As the ice retreated, it was likely pinned on at least three former grounding lines marked by topographic highs, and transverse ridges on the flanks of the basin. These may have subsequently formed pinning points for developing ice shelves. The ice shelf geometry and bathymetry measurements show that the base of the Brunt Ice Shelf now only makes contact with one of these topographic highs. This contact is limited to an area of less than 1.3 to 3 km2 and results in a compressive regime that helps to maintain the ice shelf's structural integrity. The maximum overlap between ice shelf draft and the bathymetric high is 2–25m and is contingent on the presence of incorporated iceberg keels, which protrude beneath the base of the ice shelf. We discuss the recent changes in the configuration of the ice shelf, the current status of its contact with the bed, and how these will determine the future stability of the ice shelf.

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Session11: Applied bathymetry for understanding Quaternary history and change

Past ice dynamics and unusual ramp bedforms offshore Brunt Ice Shelf, Weddell Sea

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Past ice dynamics are so far only poorly resolved in the southern Weddell Sea. This is highlighted by previous studies that led to two contradicting scenarios for the grounding line location during the Last Glacial Maximum (LGM), which differed by up to ~650 km. Another study suggested that the maximum ice extent locally was not reached during the LGM but in the early Holocene, indicating that there was also a highly dynamic ice sheet system during deglaciation. There is ambiguity about the history of ice advance and retreat in the region offshore Brunt Ice Shelf based on current data. Only one radiocarbon dated marine geological core is available, contains age reversals, and can be interpreted as indicating ice free conditions during the LGM or having been overrun by grounded ice between 30.2-20.3 cal ka BP. Today, the Brunt Ice Shelf itself is a focus of interest due to the critical crack/fracture development since 2016. This endangers Halley research station, which is situated on the ice shelf, and has resulted in the third consecutive year of austral winter closure. Geophysical ice shelf investigations revealed that, unlike usual ice shelves, the Brunt Ice Shelf consists of numerous blocks of meteoric/glacial ice that are "glued" together by freezing sea ice and snow drift. It is hypothesized that the Brunt Ice Shelf sustains its stability due to buttressing at the McDonald Ice Rumples, which form the only remaining ice shelf pinning point. Improved understanding of the past development of the ice shelf system may also aid understanding the processes active today.

We investigated hydroacoustic data that were acquired offshore Brunt Ice Shelf over the last decades with RV Polarstern and RRS James Clark Ross for geomorphological indications of past ice sheet dynamics. The identified landforms show that major ice discharge during the LGM was not via Brunt Basin just in front of the modern-day Brunt Ice Shelf, but via an ice stream that occupied Stancomb-Wills Trough, which is located northeast of Brunt Ice Shelf and extends about 200 km upstream of the modern-day grounding line. We identified at least three still stand phases during retreat in this trough. Marine geological data revealed a minimum age for grounding line retreat before 8.5 cal ka BP. In contrast, we found no indications of fast flowing ice in Brunt Basin. Instead, we infer slow flowing, cold-based ice and found uniquely formed ramp-shaped bedforms. We suggest that these ramps were formed due to the unusual structure of the ice shelf, which led to temporary grounding of ice shelf keels that acted as buttressing points for a more extensive ice shelf in the past. We will present the new ice sheet reconstruction and will discuss the formation process of the ramps.

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Session11: Applied bathymetry for understanding Quaternary history and change

Insights into controls on Thwaites Glacier retreat from new high-resolution bathymetry and related data

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Thwaites Glacier is widely-regarded as the most vulnerable large ice stream of the West Antarctic Ice Sheet. The main reasons for this are that it is not buttressed by a large ice shelf and flows on an upstream-dipping bed that continues back to deep subglacial basins beneath the centre of the ice sheet. Over the past 30 years the amount of ice flowing out from Thwaites Glacier has nearly doubled and parts of the grounding line are retreating at >1 km yr-1, highlighting an urgent need to understand processes controlling its change. Regional observations indicate that incursion of relatively warm Circumpolar Deep Water (CDW) beneath the small ice shelf is the main driver of contemporary retreat. However, radiocarbon dates from a marine sediment core only 20 km north of the front of the Thwaites Eastern Ice Shelf (EIS) indicate that the grounding line had retreated beyond this position before 10,350 years ago, implying that the present phase of retreat must have been initiated relatively recently.

Until this year few observations had been made close to the front of Thwaites Glacier due to the fact that the former Thwaites Glacier Tongue, which is now the 70 km-long iceberg B-22A, occupied the area until it calved in 2010, and there has been persistent fast ice cover west of the EIS through most subsequent seasons. Break-up of the fast ice in January this year allowed unprecedented access to the area in front of the fast-flowing axis of the glacier on RVIB Nathaniel B Palmer cruise NBP19-02, the first research cruise of the International Thwaites Glacier Collaboration.

We will present new multibeam bathymetry data collected in cruise NBP19-02 that cover an area >3000 km2 in front of Thwaites Glacier. These data reveal rugged seabed topography including elevation differences of >1000 m between the shallowest banks and the deepest troughs. The banks, some of which rise to shallower than 200 mbsl, would have been former ice shelf pinning points, while the troughs channel CDW towards the glacier. Over a wider region, dive data from tagged Elephant and Weddell seals provide bathymetric constraints in areas where no sounding data have yet been collected. We will also present multibeam bathymetry and sidescan sonar data collected during missions of a Hugin autonomous underwater vehicle, which image the seafloor at more than an order of magnitude finer resolution than the shipboard multibeam data. These data reveal enigmatic features that formed close to the retreating grounding line.

A045

Session12: Geological records of ocean and ice sheet change from the Ross Sea

Ice-sheet ocean interactions at Hillary Canyon through time (Eastern Ross Sea, Antarctica)

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The Ross Sea continental margin is one of the key areas around Antarctica to study the present and past interactions between ocean and ice-sheet dynamics. In some particular locations of the Ross Sea, warm Circum Polar Deep Water (CDW) impinges the continental shelf and mixes with cold Ross Sea Bottom Water. The Hillary Canyon, southwestern flank of Iselin Bank, is one of those locations. The Iselin Bank is inherited from times older than the presumed onset of Antarctic glaciations (~34 Ma).

Seismic stratigraphy suggest that the Hillary Canyon is an old feature of the Ross Sea continental margin. There, Ice Shelf Water (ISW) flowing out of the Ross Sea cavity, mixes with the cold bottom waters and cascades down the Hillary Canyon. What happened in this location during the Cenozoic glaciations is critical to understand how oceanic conditions influenced the advance of the Antarctic ice sheet on the continental shelf. Evidence suggest that during the past Cenozoic glaciations, large ice streams draining the West and East Antarctic ice sheet (WAIS, EAIS) contributed to the progradation and deepening of the continental margin. This in turn potentially modified both ice sheet and ocean dynamics in the area as well as the interplay between them, especially since the Miocene, when the WAIS became mostly grounded below sea level.

Ice sheet numerical simulations of the last deglaciation suggest that the Hillary Canyon played an important role during the last deglaciation in the retreat of the WAIS. This influence on the interplay between ice sheet and ocean could have been older. Here we provide a multi-disciplinary overview of the oceanic, atmospheric and ice sheet processes to link the preliminary results of IODP expedition 374, PNRA expedition 2017 and older expeditions.

We propose that given the fundamental differences in morphology between Eastern and Western Ross Sea bed, the Hillary Canyon plays a key role in the past advances and retreats of the ice sheet by modulating the heat exchange through the continental shelf edge since the mid to late Miocene.

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Session12: Geological records of ocean and ice sheet change from the Ross Sea

Miocene ice sheet oscillations in the Ross Sea embayment based on preliminary results of log-seismic correlations

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The environmental conditions of the Ross Sea have significantly changed since the early Miocene, influenced by multiple advances and retreats of the East and West Antarctic Ice Sheets. Shelf-wide extension of marine based ice into the central sector of the Ross Sea occurred during Mid-Miocene Climatic Transition, whereas ice sheet load and erosion generated landward deepening of the continental shelf by early Pliocene.

Today, the continental shelf of the Ross Sea comprises a series of shallow banks and deep basins referred to as glacial troughs. Sites DSDP272, IODP U1521 and DSDP273 are located along the middle continental shelf at water depths of 619, 562 and 495 m in the Glomar-Challenger, Pennell and Joides basins, respectively. The wells tie with high-resolution single channel seismic profiles that transect along the Mid-Miocene paleo-shelf edge. Six units can be distinguished by correlating changes in physical properties and seismic facies. They are bounded by marked stratigraphic discontinuities that can be regionally correlated using a wide network of multichannel seismic profiles available from the Antarctic Seismic Data Library System. The Miocene sedimentary section is particularly expanded in the Pennell trough (U1521). It records the transition from a period of expansion of grounded ice pinned on shallow banks during the early Miocene, to ice proximal and open water conditions during the middle Miocene, to full glacial conditions with the ice sheet reaching the paleo-shelf edge at around the time of the middle-late Miocene boundary.

A large variety of ice-distal to ice-proximal features can be correlated between logging and seismic data, revealing the Miocene ice sheet oscillations in the vicinity of the paleo-shelf edge of the central Ross Sea. In particular, high velocity layers have been distinguished in the three basins. Potentially, they represent units with high diatom (opal) content which have undergone opal-A to opal-CT diagenesis. The extrapolation of physical properties along the seismic profiles reveal the lateral continuity of these opal markers and the existence of similar depositional and diagenetic setting in different locations along the profiles. Overall, the opal layers point to repeated periods of maximum productivity in open marine conditions predating glacial advance along the ice sheet front of the Ross Sea during the Miocene.

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Session12: Geological records of ocean and ice sheet change from the Ross Sea

Cosmogenic evidence for MIS 4 timing of the local LGM in Terra Nova Bay, Antarctica

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The Jangbogo Hills are erratic-covered landforms consisting of a series of benches that parallel Campbell Glacier, northern Victoria Land, Antarctica. We sampled erratic cobbles from six benches to reveal the exposure times of glacier erratics using in situ 10Be and 26Al. The erratics from the upper three benches yield exposure ages older than Marine Isotope Stage (MIS) 4, with most exposed since MIS 5 after removing the samples with multiple exposure signals. However, the lower three benches exhibit tight clusters of exposure ages that range from MIS 3 to the Holocene. Campbell Glacier underwent rapid downwasting from its maximum position at the Penultimate Glacial Maximum (PGM) during MIS 5, centered at 98.3 ka. This downwasting continued throughout the last glacial period, with potential minor fluctuations and stagnation around a bench (~90 m asl) between 35.5 and 17.1 ka. Our cosmogenic results highlight three important points concerning the glacial history of Terra Nova Bay since the PGM in northern Victoria Land, Antarctica: 1) Campbell Glacier was thicker at the PGM than at the Last Glacial Maximum (LGM); 2) the local LGM occurred at MIS 4, which is earlier than the global LGM; and 3) the extent of Campbell Glacier during the last glacial period was much smaller than that commonly assumed. The assumption that the local LGM (MIS 4) in Victoria Land, Antarctica was synchronous with the global LGM (MIS 2) should be treated with caution.

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Beyond J9: New observations of the hidden ocean and sea floor sediments beneath the Ross Ice Shelf, West Antarctica

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Direct observations of present-day conditions and sea-floor sediments in the central region of the Ross Ice Shelf indicate a system characterised by long quiescent periods but capable of rapid change. Our evidence comes from two boreholes drilled using hot water at a site ~320 km upstream of the present-day calving front (~80°39′ S, 174°28′ E). Over 2 weeks in early December 2017, we made repeated temperature, salinity, current, and turbulence measurements through the ~428 m water column, collected 11 sea-floor sediment cores and collected sediments from within the ice shelf.

Ice at the site is ~367 m thick and originates in the glacier-left margin of Liv Glacier. A ~60 m thick basal layer of bubble-poor ice containing unevenly distributed sediment was observed at both boreholes. The contact between the overlying bubbly glacier ice and the bubble-poor glacier ice layer is abrupt and steep. The sediment chemistry is consistent with a source in the Transantarctic Mountains and no diatoms were recovered from the deep ice layer. It is thus not marine in orgin and must instead have been accreted on in the terrestrial environment and been preserved over the ~800 years since the ice entered the shelf.

Ocean conditions are similar to those observed 4 decades ago at the "J9" site (82°22′ S, 168°37′ W). The oceanic boundary layer at the base of the ice shelf is cold (~-2.12°C), relatively fresh (32.4 to 32.5 psu) and a few 10s of m thick. This layer is separated from a benthic ~50 m high salinity (34.7 to 34.8 psu) layer by a more variable intermediate layer. A very thin layer of platelet ice was observed at the base of the ice shelf. The layer may reflect a local transition to freezing conditions or a more ephemeral (on an unknown time scale) process. There is no evidence of persistent re-freezing along the ice shelf flow band.

Sea-floor sediments recovered via gravity coring contained a highly compacted basal diamict overlain by 47 cm of granule-sized mud pellets and capped by 7 cm of mud with infrequent dropstones, indicating minor Holocene basal melting. The sediments contain reworked late Miocene to early Pliocene diatom fragments in an assemblage that appears similar to the assemblage at J9. Magnetic fabric analysis indicates a gradual decline in current strength and an episode of re-grounding within the till pellet facies. Thus most of the sediment record is of near-grounding line conditions.

Taken together, the emerging picutre is one of persistent post-LGM ice cover in the Ross Ice Shelf embayment, consistent with the slow rates observed today. However, while we are still working on dating the sequence, the transition from near-grounding line to distal-grounding line appears to have been rapid.

This research was facilitated by the New Zealand Antarctic Research Institute (NZARI) funded Aotearoa New Zealand Ross Ice Shelf Programme and the Victoria University of Wellington Hot

Water drilling initiative. We thank the hot water drilling team led by A. Pyne and D. Mandeno. Logistics support was provided by Antarctica New Zealand.

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Rapid and Dynamic Mid-Holocene Thinning of David Glacier, Antarctica

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Geological reconstruction of changes in the Antarctic Ice Sheet (AIS) through time provides critical context for understanding Antarctica's contribution to past, present, and future global sea level and climate change. Modern and historical observations of the AIS only extend back nearly 100 years, and therefore do not capture the full variability and behavior of the ice sheet which respond over longer periods. A geological perspective is required to quantify how the ice sheet evolves over centennial to millennial time scales, which have potential to provide insight into rates of ice sheet change which we might see again in the near future. Further, integration of the marine extent and terrestrial thickness of an ice mass through time provides a robust data set for evaluation of numerical ice sheet model simulations, which are used to predict future ice sheet contributions to sea level. Onshore, surface exposure ages of glacial deposits are used to track the upper surface of the ice sheet.

Here we present the first high-resolution, terrestrial thinning reconstruction for David Glacier, the largest East Antarctic outlet glacier in Victoria Land. Thinning profiles from two sites, Hughes Bluff along the Scott coast and Mt. Kring over a hundred kilometers inland towards the interior of the East Antarctic Ice Sheet, show that David Glacier experienced a period of rapid, dynamic thinning of up to ~2m/yr during the Mid-Holocene. Regionally, this dramatic thinning event correlates with episodes of rapid ice surface lowering and retreat from stable marine configurations at nearby outlet glaciers (Mackay, Mawson and those within Terra Nova Bay) along the Transantarctic Mountains (TAM). Together, this shows that the outlet glaciers along the Scott Coast, western Ross Sea experienced rapid, simultaneous, and regional thinning. The cause of this dramatic change is currently not clear but takes place ~2 kyr after southern retreat of grounded ice in the Ross Embayment. Potential mechanisms for regional outlet glacier thinning and retreat include a previously unrecorded influx of marine heat and/or marine ice sheet instability and/or dynamic effects associated with an early Holocene decoupling from the retreating ice sheet/shelf. Importantly, these events are currently not represented in numerical modelling reconstructions aimed at understanding the processes that influenced the past behavior of the AIS.

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The ODYSSEA Contourite Depositional System. Interpretation of seismic reflection profiles collected between the Iselin Bank and the Hillary Canyon (Ross Sea).

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Oceanic currents carrying relatively warm waters at the base of the Antarctic Ice Sheet could play a key role in terms of ice mass balance loss. Assessing how the oceanic circulation interacts with the ice sheet today and in the past is fundamental to better understand its stability and to predict future global sea level rise.

The Earth experienced a wide range of different climatic conditions during its history and in the geological record precious information about how the Antarctic Ice Sheet and the oceanic currents reacted to past climate change are stored.

The sedimentary record of the continental slope and rise between the Iselin Bank and the Hillary Canyon is a key area in understanding how the ice sheet and the oceanic currents are linked. Indeed the Iselin Bank, protruding northwards for about 150 km from the Ross Sea continental shelf, represents an anomaly in the east-west direction of the Ross Sea continental slope. This bathymetric anomaly deviates the flow of the Antarctic Slope Current (ASC) as well, that is forced to flow northward along the eastern continental slope of the Iselin Bank. In correspondence of the direction change in the continental slope represented by the Iselin Bank there is the Hillary Canyon, through which sediments and dense and cold bottom waters forming on the continental shelf flow downslope, mixing with upslope flowing warm Modified Circumpolar Deep Water (MCDW).

Therefore the combination of morphobathymetric and oceanic features make this a potential area of intrusion of relatively warm waters on the continental shelf.

In 2017 new data have been acquired by the research vessel OGS Explora within EUROFLEETS funded ANTSSS project and PNRA funded ODYSSEA project, including single channel seismic lines, CHIRP profiles, morphobathymetric and oceanographic data.

By integrating seismic lines and morphobathymetric data seven seismic stratigraphic units have been identified. The three lower units are filling and smooth basement irregular morphology while the four upper units show thickness variations not directly related with the basement. Mound shaped reflectors laterally terminating in downlap are interpreted as sediment drifts forming under the influence of bottom currents. The overlap of these sediment drifts and related erosional features results in a Contourite Depositional System.

The flanks of the reliefs are modified by the presence of detachment scars, found throughout the dataset.

The combined activity of gravity driven processes and bottom currents in shaping the sedimentary record is testified also by a thick Mass Transport Deposit dominating the central part of the Contourite

Depositional System.
These seismic lines are crossing sites U1523, U1524 and U1525 of IODP 374 expedition. Lithological and petrophysical information coming from these sites will help the correlation of seismic units and the attribution to depositional processes.

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Antarctic ice-sheet behavior in the Ross Sea outer continental margin in the late Miocene to early Pliocene from preliminary results of regional seismic stratigraphy and IODP Site U1522

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Reconstruction of paleobathymetry and seismic stratigraphic mapping in the Ross Sea outer continental margin allows us to understand past Antarctic ice-sheet behavior and associated sedimentary processes. Two major glacial unconformities, namely, the Ross Sea Unconformity 3 (RSU3) and RSU2, were recognized and mapped in the Ross Sea continental shelf by the Antarctic Offshore Stratigraphy (ANTOSTRAT) project in 1995. These unconformities represent major changes in the architecture of the continental margin, although the lack of seismic and drill site data from some of the sectors in the continental shelf and slope prevented to fully understand time and mechanism of their formation so far. Here we present the preliminary results of the paleobathymetric reconstruction at the time of RSU3 and RSU2 (late Miocene to early Pliocene) formation, based on the core-log-seismic correlation of IODP Exp. 374 Site U1522 and adjacent seismic profiles in the eastern Ross Sea outer continental margin. The seismic facies between RSU3 and RSU2 were compared with lithostratigraphy and physical properties from sediment core and downhole logging results of Site U1522. The RSU3 and RSU2 seismic reflectors were traced into the eastern and central Ross Sea outer continental shelf, slope, and rise using the information from IODP Exp. 374, DSDP Leg 28 sites and additional seismic lines collected since 1995, including the data acquired during the OGS Explora Expedition in 2017 and the Araon Expeditions in 2013, 2015, and 2019. This constitutes a major improvement as well as a spatial extension that builds upon the paleobathymetric maps produced in the framework of the ANTOSTRAT project. Spatio-temporal distributions of seismic facies, stratal geometry, and the location of the sediment depocenters provide useful insights into the paleodepositional environment, influenced by subglacial, ice-proximal and ice-distal glaciomarine processes. Those new maps, combined with drill site data, will help to understand the characteristics of sedimentary stacking patterns and the paleoshelf break evolution in different areas of the Ross Sea. In fact, this area has been influenced by the activity of different ice-streams from the late Miocene to early Pliocene periods. The new paleobathymetric maps will serve as boundary conditions to ocean and ice sheet modeling and improve the understanding of ice-sheet-ocean interactions during this period and in particular the interplay between East and West Antarctic ice sheet.

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Climate thresholds, marine ice sheet expansion, and the role of sea ice across the Miocene Climate Transition.

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Less than a million years in duration, the Miocene Climate Transition (MCT) records one of Earth's most recent major shifts in climate. During this interval, conditions changed from peak warmth of the Miocene Climate Optimum (MCO), when average temperatures were 3 to 4°C warmer than today, to a cold climate where Antarctica's ice sheets were more extensive than today. These major changes occurred under CO2 concentrations that were like today and those expected in the coming decades. Deep sea oxygen isotope (δ18O) records indicate that mid-Miocene cooling began ~ 14.8 Ma and culminated in a major climate shift at 13.8 Ma. Post MCT interglacial δ18O values are like those that characterise pre-MCT glacial episodes, which suggests that ice volume and bottom water temperatures that characterise post-MCT interglacials were like mid-Miocene glacial intervals. The climate transition coincides with a drop in CO2 from > 500 ppm at 14.8 Ma to < 400 ppm by 13.7 Ma and is followed by major turnover in Southern Ocean diatoms. Traditional interpretations of the MCT suggest that expansion and stabilisation of the East Antarctic ice sheet occurred at this time. However, these inferences are primarily based on far-field records, and rare and sparse outcrop in the Transantarctic Mountains (TAM). Here, we examine environmental change in Antarctica through the MCT using geological data from sediment cores, including glacial marine sediments at the margin of the Ross Sea and glacial-fluvial sequences in the TAM. We integrate these data with published δ18O records. Finally, we utilise a climate model to simulate the influence of changes in atmospheric carbon dioxide and Earth's axial tilt on Antarctica.

Our analysis indicates that ice sheets were predominantly land-based through much of the MCO with glacial-interglacial variations mainly paced by changes in orbital eccentricity. Climatic cooling between ~ 14.8 Ma and 14 Ma, likely driven by a decline in atmospheric CO2 concentration, caused sea ice to expand during glacial intervals (cold orbits). Ocean dynamic and albedo feedbacks associated with sea-ice expansion enabled ice sheet advance across Antarctica's continental shelves during these glacial episodes. But CO2 remained high enough to drive sea ice reduction and ice sheet retreat to locations landward of the terrestrial continental margin under warm orbits. Notably, this interval records peak environmental sensitivity to changes in obliquity.

A major shift in the climate system occurred between 13.8 and 13.7 Ma and was likely associated with a reduction in CO2 below 400 ppm. Major erosional disconformities in offshore drill cores indicate that marine ice sheets became a persistent feature in the Ross Sea at this time. Terrestrial paleoclimate records indicate that average atmospheric temperatures dramatically declined, and inland regions became hyper-arid at high altitudes. We infer that extensive sea ice was able to persist through consecutive glacial-interglacial intervals following this climatic shift, even under the warmest orbital configurations. We suggest this shift to persistent sea-ice, and associated albedo feedbacks, contributed to cooling climate and increasing aridity inferred from terrestrial glacial deposits in the TAM.

Proxy records indicate that CO2 varied through the late Miocene, at times exceeding 400 ppm.

Sedimentary records from the Antarctic margin indicate that marine-based portions of the ice sheet retreated from marine basins during these times of elevated CO2. Whereas the MCT represents a major shift in Earth's climate, geological data show that high latitude climate and Antarctica's ice sheets did not stabilise across this transition. If CO2 concentrations continue to rise and remain high, geological data suggest Antarctic sea ice will decrease in extent, the Antarctic ice sheet will retreat inland, and warmer and wetter conditions will return to the Transantarctic Mountains.

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Glacio-marine sedimentation influenced by the Ross Ice Sheet in the continental slope and rise to the east of Pennell-Iselin Banks in the Ross Sea

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The repeated advance and retreat of the Ross Ice Sheet has been operating as an important factor to affect on the glacio-marine sedimentation in the continental shelf, slope, and rise of the Ross Sea. However, the studies of glacio-marine sedimentation in the continental slope and rise are quite lack, compared with those in the continental shelf of the Ross Sea. During XXIX PNRA expedition (Rosslope Ⅱ), three box cores (RS14-BC1, BC2, BC3) and three gravity cores (RS14-C1, C2, C3) were obtained in the continental slope and rise to the east of Pennell-Iselin Banks to understand the glacio-marine sedimentation change related to the activity of the Ross Ice Sheet between the glacial and interglacial periods. The sedimentological (grain size, magnetic susceptibility), geochemical (total organic carbon, total nitrogen, C/N ratio, biogenic opal, CaCO3), and isotope (δ13C of organic matter and δ15N of bulk sediments) properties were analyzed along with AMS 14C dating of bulk sediments. The sediment cores consist mostly of hemipelagic sandy clay or silty clay with sparse ice-rafted debris (IRD). The lithology of sediments was divided mainly into the two units (A and B), and Unit B was subdivided into the two subunits (B1 and B2) based on the sediment color and sedimentological and geochemical properties. Unit A indicates the interglacial sedimentation originated mainly by the suspension settling of biogenic and detrital particles with sparse IRDs under open marine condition. Unit B1 corresponds to the degalcial sedimentation with an increasing of IRDs during the transition period from Unit B2 to Unit A. Unit B2 characterized by different properties from Unit A represents the glacial sedimentation. We suppose that the sediments of Unit B were mainly transported either by the continuously lateral melt-water plume under the ice sheet or by distal part of debris flow originating from the front of grounding line in the subglacial continental shelf under the ice shelf during the glacial and deglacial period. Hence, Unit B contains the reworked and eroded sediments from the continental shelf. However, the influence by these shelf sediments during the glacial and deglacial period was apparently limited to Site C2 (1757 m deep) in the continental slope to rise of in this part of the Ross Sea. The biogenic opal and TOC contents during the glacial period are high at Site C1 (2372 m deep) in the continental rise, which suggests that an open marine condition occurred seasonally and occasionally. Thus, the increase of sediment supply to the continental slope and rise of the Ross Sea during the glacial and deglacial periods is closely related to the growth activity of the Ross Ice Sheet.

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The dynamism of valley glaciers along the Borchgrevink coast (North Victoria Land, Antarctica) archived in the offshore Quaternary seabed landforms and within the Miocene buried glacio-fluvial delta

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The area of study stretches for 60 - 80 km offshore the Borchgrevink coast in the North-Western Ross Sea from about 73°20' S to 72°36' S of latitude. It is a significant zone for its location within the tectonic Northern Basin and the proximity to the Drygalski Trough, where repeated oscillations/ice grounding events of the AIS (Antarctic Ice Sheet) from the south and of North Victoria Land glaciers from the west occurred during the Late Neogene.

The sparse already available geophysical data were combined with seismic, chirp and multibeam data collected during the 2017 OGS/Explora survey (GLEVORS PNRA project, Glacial EVOlution in the north-western Ross Sea, offshore North Victoria Land - Antartica). Such data were integrated with the collection of two sediment gravity cores, acquired north of the Coulman Island, and with oceanographic measurements (currents by vessel mounted Acoustic Doppler Current Profiler and temperature by Expendable Bathythermograph probes), gathered mostly in the outlet area of the Borchgrevink valley glacier and in the middle of the Drygalski Trough.

This study aims at investigating the deglaciation of the coastal glaciers offshore the Borchgrevink coast, and reconstructing the paleo ice drainage in the area since at least the Lower Pliocene(?) through Quaternary to LGM.
In particular, seismic data recently acquired have highlighted the presence of a coastal composite Grounding Zone Wedge (GZW) which formed during the pauses in the LGM grounding-line retreating of the Borchgrevink and Mariner glaciers, and the existence, northward, of a smaller and isolated grounding wedge deposited in front of the Tucker glacier.

The studied Borchgrevink coastal valley glaciers in the Quaternary time were not coalesced, and probably they advanced and retreated asynchronously: the northern sedimentary wedge of the Tucker glacier is indeed interpreted older than the southern one. Ice-distal small-scale recessional landforms, as arcuate moraines and corrugation ridges, record peculiarities of deglaciation in this area. The Holocene ice flowing lines pattern is recorded in the morpho bathymetry that shows 1) the glacial lineations imprinted within the Drygalski Trough and 2) those lineations, partially superimposed and with a radial orientation, left on the coastal composite grounding zone wedge. The ice marginal and proglacial domains of the northward-flowing Mariner-Borchgrevink glaciers are displayed in the composite GZW and in the more distal zone, which merges into the subglacial domain of the southern ice streams and is variously affected by icebergs ploughmarks.
Under the larger GZW of the inferred Borchgrevink-Mariner glaciers a buried wedge feature appears to continue down-dip a gentle paleo slope and is interpreted as the highest part of a Pliocene(?) old

fluvioglacial delta system. This ancient delta built-up at the edge of wet-based still-standing glaciers by successive sediments outwashes. It deposited over the regional unconformity RSU2 of ANTOSTRAT (Brancolini et al.,1995) and was preserved by the successive glacial erosion, remaining embedded within the extensive prograding glaciomarine clinoforms of the Antarctica Ice Sheet (AIS) ice streams (4.75 - 3.4 Ma or 2 - 0.71 Ma?) that repeatedly advanced to the continental shelf edge.

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Early to middle Miocene oceanographic conditions in the Ross Sea, Antarctica

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Numerical models indicate that the Ross Sea sector is sensitive to ocean and atmospheric temperature variations. Thus, studies of regional ice sheet behavior during past warm climate intervals should improve predictions of cryosphere response to ongoing and future warming.
Geologic records indicate sustained global warmth, reduced equator-to-pole thermal gradients, reduced ice volume, and changes in carbon cycling during the Miocene Climatic Optimum (MCO; ~17-14.5 Ma). Because atmospheric pCO2 fluctuated within a narrow range (300-500ppm) during the MCO, enhanced climate sensitivity and/or additional forcings/feedbacks were likely responsible for high-latitude MCO warmth and subsequent cryosphere expansion during the middle Miocene climate transition (~14 Ma; MMCT).

To understand how ocean-ice sheet interactions influenced Miocene Antarctic cryosphere expansion, International Ocean Discovery Program (IODP) Expedition 374 recovered an early Miocene to Quaternary sedimentary sequence from Site U1521 (75°41.0351'S, 179°40.3108'W, 562 m water depth), on the continental shelf of the central Ross Sea. Diatom-bearing/-rich mudstones indicate open marine deposition over the Ross Sea shelf during the MCO (~17-16 Ma). A hiatus exists between ~16 and ~14.6 Ma, suggesting ice expansion in the central Ross Sea during the MCO, before ice expansion during the MMCT. An interval of interbedded diamictite and diatom-bearing mudstone dating to ~14.6-14 Ma indicates an interval of ice-proximal deposition immediately before the MMCT.

Here we present an orbital-scale early to middle Miocene upper ocean temperature (TEX86) record from Site U1521, which reveals ~5°C of warming from ~17-16 Ma. Orbitally-paced temperature fluctuations are superimposed on this general warming trend. The TEX86 record, combined with lithofacies, XRF scanning, palynologic, foraminiferal, and geochemical analyses from Site U1521, coupled with results from ANDRILL-2B, provides insight into the ice-proximal to open marine conditions in the Ross Sea during the early to middle Miocene. This integrated paleoenvironmental approach is required to elucidate the timing, mechanisms, and feedbacks associated with early to middle Miocene Antarctic cryosphere and global climate system development. The record suggests orbitally-paced changes in heat/moisture transport to the Ross Sea during the MCO may have resulted in middle Miocene ice expansion.

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Pleistocene deep-water oxygenation during interglacial events in the Ross Sea, Antarctica: palaeomagnetic results from IODP Exp. 374

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Seismic imaging and scientific drilling in the Ross Sea has demonstrated substantial fluctuations in the size of the West Antarctic Ice Sheet (WAIS) during the Plio-Pleistocene. Changes in the flux of ocean heat onto the Antarctic shelf has been postulated as one of the main drivers for the variability of the WAIS. To test the extent of oceanic influence on past stability and extent of the WAIS, it is necessary to combine oceanographic records with reconstructions of WAIS behaviour on glacial–interglacial timescales, which is now possible using drillcores recovered during International Ocean Discovery Program (IODP) Expedition 374 to the Ross Sea. Notably, the drillcores recovered at IODP Site U1524 are suitable for the oceanographic reconstructions since this site is ideally situated on the southeastern levee of the Hillary Canyon – one of the largest conduits of Antarctic Bottom Water.

Pronounced variability in Pleistocene palaeomagnetic signals at Site U1524 indicates rapid alternations in sediment minerology over the past ~2 Myr. A magnetite phase is consistently present throughout the sequence, but a higher-coercivity maghemite phase only occurs in several discrete intervals. Maghemite forms when magnetite oxidises, which typically occurs in the oxic zone close to the sediment–water interface. Thus, these maghemite-rich intervals are interpreted to reflect buried oxic zones, similar to those observed in short sediment cores from the west side of the Antarctic peninsula (RSS James Clark Ross JR298). We hypothesise that these buried oxic zones represent a transient increase in oxygen concentrations in deep-waters around West Antarctica during Pleistocene interglacials. The well-oxygenated conditions during interglacials may relate to efficient air–sea exchange of oxygen during reduced sea ice coverage on the Ross Sea shelf. Part of the reduced sea ice coverage may be driven by impingement of (warm) modified circumpolar deep water onto the Ross Sea shelf through Hillary Canyon during warmer intervals, which may have also contributed to the reduced interglacial extent of the WAIS.

A426

Session12: Geological records of ocean and ice sheet change from the Ross Sea

Early Holocene sea-ice changes in the northwestern Ross Sea

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Laminated diatom oozes accumulating in Antarctic coastal basins provide an excellent opportunity to compile high-resolution paleoclimate records that can capture Holocene ocean-atmosphere variability at decadal to multi-millennial timescales. Diatom silica preserved in marine sediments reflects spatial variations in the productivity of the overlying water column. Core-top diatom assemblages have well-documented associations with specific environmental conditions such as presence of sea-ice, light and nutrient availability, sea-surface temperature, and water column stratification. The relationship between sediment geochemistry, diatom assemblages, and related environmental conditions can therefore be utilised to reconstruct a range of climatic conditions at a particular site through time. Here we present results from core RS15-LC62, which was collected from an isolated basin in Moubray Bay in the northwest Ross Sea. The core, which is 4.7m long and records 3,000 years of climate and environmental change in the Early Holocene, is composed of diatomaceous ooze deposited after the ice sheet had retreated from the northwest sector of the Ross Sea. Core images and stable isotope geochemistry show that LC62 has unique characteristics not observed in many Antarctic sediment cores. Firstly, δ13C isotope values at the base of the core are very negative (-33‰), in comparison to those typically observed in the coastal Ross Sea (-24-25‰), and become more positive up core (-27 to -30‰). Secondly, the lower portion of LC62 (2.3 – 4.7mbsf) is characterised by undulating and interweaving layers of diatom ooze with different colours and textures, whereas the upper portion comprises horizontally laminated diatom ooze typical of Antarctic coastal basins. The laminae in the top of the core are differentiated by changes in colour (cream, orange, and olive), texture (massive and fluffy) and density. Light and dark pairs of laminae dominate the upper section. Light laminae are interpreted to record early season productivity and are dominated by Corethron pennatum. C. pennatum have been associated with low winds, a stratified water column and open water. Dark laminae, formed later in the growing season, are dominated by Fragilariopsis curta, which is commonly associated with the sea-ice edge and congelation ice. Other laminae dominated by Chaetoceros resting spores record times of high productivity in a lower salinity, nutrient rich surface layer. This core constrains the timing of ice sheet retreat in Moubray Bay and records changes in sea-ice and ocean upwelling close to the edge of the Ross Sea and continental shelf.

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Estimates of West Antarctic Ice Sheet sediment and ice flux of the Bindschadler Ice Stream during the post-LGM

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Sedimentation at the grounding zone tends to stabilize the extent of marine-terminating ice sheets against either sea-level rise or dynamic thinning. Here we synthesized published glacial-geological and geochronological results from the outer continental shelf of the Whales Deep Basin (WDB) in the eastern Ross Sea to generate an erosion rate.
For the period between 14.7 and 11.5 ^{14}C kyr BP, the average paleo-erosion rate over the entire drainage basin was 0.7 mm/a and the associated sediment flux was 1.7 x 10^8 m^3/a. These constraints suggest a ~600 m/a lower bound long-term average velocity for the deforming till and a 3-m upper bound average thickness for the deforming till layer. Towards the latter part of the grounding, the paleo-Bindschadler Ice Stream (paleo-BIS) discharge accelerated following paleo-ice-shelf breakup creating a strongly negative mass balance that exceeded 37 gigatons/a. In comparison to the Amundsen Sea sector, our calculations highlight the instability of the modern Pine Island Bay and Thwaites ice streams, whose combined ice-volume discharge currently exceeds the paleo-discharge of BIS that existed prior to a major 200-km retreat in the extent of grounded ice in the Whales Deep Basin.

A077

Session13: Past Climate Variability of the Southern Ocean and its Global Teleconnections

Recent change in SAMW and its impact on the Southern Ocean warming

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Subduction and export of Subantarctic Mode Water (SAMW) supplies the upper limb of the overturning circulation and makes an important contribution to global heat, freshwater, carbon and nutrient budgets1-5. Upper ocean heat content has increased since 2006, helping to explain the so-called global warming hiatus between 1998 and 2014, with much of the ocean warming concentrated in extratropical latitudes of the southern hemisphere in close association with SAMW and Antarctic Intermediate Water (AAIW)6,7. Here we use Argo observations to assess changes in thickness, depth and heat content of the SAMW layer. SAMW has thickened (3.6±0.3 m yr-1), deepened (2.4±0.2 m yr-1) and warmed (3.9±0.3 Wm-2) between 2005 and 2015. Wind forcing, rather than buoyancy forcing, is largely responsible for the observed trends in SAMW. Most (84%) of the increase in SAMW heat content is the result of changes in thickness; warming by buoyancy forcing (increased heat flux to the ocean) accounts for the remaining 16%. Projected increases in wind stress curl would drive further deepening of SAMW and increase in heat storage in the southern hemisphere oceans.

A211

Session13: Past Climate Variability of the Southern Ocean and its Global Teleconnections

Effects of environmental conditions on diatom communities and the δ13C of particulate organic matter in Terra Nova Bay.

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There is an urgent need to better understand the assimilation of carbon by diatoms in the Southern Ocean. In the Antarctic, diatoms are the most abundant and diverse microfossil group to be preserved in sediments, providing a potential window into the past. Here, we present an investigation into the modern diatom ecology and related stable isotope geochemistry of water column samples from the NBP18-01 expedition in the Ross Sea. 100 paired analyses were undertaken for diatom assemblages and carbon stable isotopes, displaying a strong positive correlation between absolute diatom abundance and the δ13C of suspended particulate organic matter. Cluster analysis of diatom assemblages grouped the samples into four distinct spatial and temporal groups, with the two most populous groups, Cluster 2 and Cluster 3, from the northern and southern Terra Nova Bay regions respectively, defined by a latitudinal boundary at 74.9 °S. South of this boundary, sustained katabatic winds interact with surface waters and result in intense mixing and sea ice formation, while north of 74.9 °S the embayment is relatively sheltered from such atmospheric forcing.

The δ13C of POC samples were observed to group distinctly in line with clusters, with elevated values (from -24 to - 21 ‰) observed in cluster 3 from northern Terra Nova Bay, and more negative values (-23 to -29 ‰) observed in Cluster 2 from southern Terra Nova Bay. The most positive δ13C values that were observed align with highs in the absolute diatom abundance and the relative abundance of Fragilariopsis curta. Low values of δ13C were seen to occur in samples with increased relative abundances of Chaetoceros resting spores, and simultaneous decreases in both F. curta and absolute diatom abundance.

While it is possible that there is a significant influence from taxon-specific fractionation effects, namely that of F. curta, we suggest that particulate organic matter δ13C appears to be most significantly driven by primary productivity in the region. Significant regional enrichment and depletion in 13C appears to result from environmental conditions including water column stratification driven by sea ice melt and low winds, and wind-induced deep mixing respectively.

A342

Session13: Past Climate Variability of the Southern Ocean and its Global Teleconnections

Revisiting 'Iron Hypothesis': Productivity Variability at the Subtropical Front on Multi-Millennial Timescale

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A link has been proposed between the aeolian dust flux and the climate of the earth. Enhanced dust supply is observed during the past glacial periods that can be two to five times of that during the interglacial periods. Dust can affect the global climate through several ways amongst which fertilization of the HNLC (High Nutrient, Low Chlorophyll) regions (mainly the Southern Ocean, and the North and Equatorial Pacific) by iron-bearing dust is an important one. The increase in productivity in such regions would result in additional uptake of carbon in the marine ecosystem resulting in the drawdown of the atmospheric CO2. However, present-day iron-fertilization experiments have failed to reproduce such a large-scale, sustained productivity increase that would result in substantial CO2 drawdown. In this scenario, the response of productivity to the past episodes of dust increase can provide a clue. Here we present a record of productivity variability from the Subtropical Front of the Indian Ocean sector of the Southern Ocean for the past 71 Kyr. The sediment core ABP-S1 was collected from a water depth of 3500 m from 42 °S latitude and 48 °E longitude. To reconstruct the past productivity in this region, several isotopic (oxygen and carbon isotope ratio of foraminifera, carbon and nitrogen isotope ratio of sedimentary organic matter), and geochemical (total organic carbon and nitrogen content) proxies were studied. We compare our results with the EDC dust flux representing global dust concentration and ODP1090 Fe mass accumulation rate (MAR) from the Atlantic sector of the Southern Ocean representing iron-bearing dust input in the Southern Ocean. The dust influx and Fe MAR increases during the MIS 2 and the MIS 4 but the response of the productivity is ambiguous raising doubts on the connection between aeolian dust influx and global climate via ocean fertilization.

A416

Session13: Past Climate Variability of the Southern Ocean and its Global Teleconnections

Pliocene-Pleistocene surface productivity along the Wilkes Land Margin, East Antarctica

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Marine-based glaciers fronting the East Antarctic Ice Sheet are susceptible to retreat due to warming ocean waters. During the mid-Pliocene (3.2 Ma) when the climate was analogous to anticipated future warm conditions, the EAIS contributed 3-10 meters to the global mean sea-level (Cook et al., 2013). Studying the variable nature of the Pliocene-Pleistocene climate improves the parameterization of the Southern Ocean. Here, we present a diatom-based reconstruction of Plio-Pleistocene environmental conditions from 1.7-3.8 Ma, from continental rise site U1361A, located near the outlet of the Wilkes Subglacial Basin. The diatom assemblage is impacted by the extent of sea-ice, water mass circulation and the position of the Polar Front, where cold Antarctic surface waters sink below less dense surface waters. The assemblage from interglacial intervals reveals progressive cooling during the mid to late Pliocene disrupted by a warm incursion at 3.2 Ma. At 2.75 Ma, there is an increase in the frequency of peaks in the Biogenic Silica content (BSi wt%) record. High BSi wt% intervals reflect periods of elevated diatom productivity and/or low terrigenous input. Diatom species with a preference for cold, open-ocean conditions become more abundant as cooling progressed into the Pleistocene.

A061

Session14: Marine sedimentary records of Antarctic ice-sheet dynamics and Southern Ocean history during the Late Cainozoic

Post-breakup deposition off Prydz Bay (East Antarctica) with Focus on Cenozoic Environments

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The area off Prydz Bay is the huge deep-water sedimentary basin which formed during rifting and break-up between India and Antarctica. The upper part of this basin was deposited under the influence of Antarctic glaciation started in the Late Eocene time. The large amount of MCS data was collected in this region by Australian, Japanese and Russian Antarctic expeditions. The average space between seismic lines ranges between 30 and 50 km but only few liens acquired recently in Russian cruises allow estimation of full sedimentary thickness (up to 10 km in the depocenter).

Seven major seismic horizons numbered up-section from CS1 to CS8 and crystalline basement are identified in sedimentary cover of the deep-water basin. All of them are generally continuous reflectors separating seismic units with different internal reflection patterns, have a regional distribution, can be recognized on the all seismic sections, and presumably correspond to principal changes in the depositional environments. Horizon WL1 is recognized in the lower part of stratified section. It onlaps the crystalline basement surface close to the continent-to-ocean boundary and is interpreted to be the break-up unconformity formed at about 125-120 Ma. Horizon CS2 is presented by a moderate to strong reflectors. The time of CS2 formation is difficult to define but it can be tentatively correlated with the opening of gateways in the southern hemisphere in the Late Cretaceous. Horizon WL3 marks the upward transition in character of an acoustic record. The overlying strata show evidence of subdued channel-levee complexes and we infer that their appearance is connected with the onset of continental glaciation in the Late Eocene and increase of periglacial fluvial activity in the coastal regions of Antarctica (namely, in the Lambert rift valley and the Prydz Bay shelf). Horizon CS4 is the most prominent interface in the sedimentary cover almost everywhere on the East Antarctic margin exhibiting a profound change in the seismic reflection pattern. This horizon heralds initiation of active mass-wasting processes (well developed channel-levee systems and gravity flow deposits). It is widely accepted that this horizon correlates with the onset of large-scale Antarctic glaciation at about 34 Ma. Horizons CS5, CS6, CS7 and CS8 show successive changes in seismic facies (CS5 marks wider distribution of channel-levee complexes; CS6 – development of contourite drifts and mud waves; WL7 – formation of large debris flow deposits). The ages of horizons are derived from ODP drilling (Site 1165) and are 23-24 Ma, 21-20 Ma, 14 Ma, 5-3 Ma, correspondingly.

Based on suggested seismic stratigraphy we compiled isopach maps for all seismic units and sequences bounded by major horizons. These maps give the important information about depositional environments and preferential pathways for sediment transport for different time intervals. The following rates of sedimentation were estimated (with maximum rates in depocenters): 60 m/m.y. for post-rift, pre-glacial Unit (CS1-CS4); 90 m/m.y. for syn-glacial Unit (CS4-Sea floor); 100 m/m.y. (up to 140 m/m.y.) for Oligocene sequence (CS4-CS5); 160-180 m/m.y. for Early Miocene Sequence (CS5-CS7); 40 m/m.y. (up to 70 m/m.y. in the local sediment drift) for Late Miocene Sequence (CS7-CS8). This research is supported by RSF Grant 16-17-10139.

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Identification of elemental composition of smectite tracing the sediment provenance in the glacial-interglacial period: Bellingshausen Sea

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Variation in clay mineral assemblages are widely used to interpret the sediment provenances during glacial-interglacial period. However, smectite clay mineral have a variation in the elemental composition that possibly transported from the multi sediment sources. Such that investigation on the elemental composition of smectite at a nano scale is inevitable to differentiate the source of sediment with a certainty. Sediments from the Bellingshausen Sea site (BS17-GC04, BS17-GC15, GC359 and GC360) that may be influenced by multiple sediment sources from the Ronne Entrance and Beethoven Peninsula were tested in this study. Grain size distributions, clay mineralogy and elemental composition of smectite from the Bellingshausen Sea sediment was investigated to puzzle out the sediment provenance that was inconsistent with clay mineral assemblages of GC359 and GC360 which are located at a close distance. Clay size fraction less than 2 μm was used to measure mineralogy and semi-quantification analysis with depth by X-ray diffractometer (XRD). Smectite, illite, chlorite and kaolinite are dominant phase in sediments. Variation in the elemental composition of smectite of GC360 during glacial period was displayed in the tertiary diagram (Mg-Al-Fe), suggest that two type of smectite, Al-rich and Al-poor smectite, supplied from the multiple sediment provenances. Therefore, these results demonstrated that elemental composition of smectite with the clay mineral assemblage as an essential tool for differentiate the origin of the sediment.

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Early resumption of dense shelf water production during the past deglaciations

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The production of Antarctic Bottom Water (AABW) today is restricted to four main locations on the Antarctic margin. AABW originates as dense shelf water (DSW), which is exported down the continental slope where it mixes with ambient water to ventilate the deep ocean. The production of AABW is dictated by strength of sea-ice production, ocean/ice shelf interactions and the geometry of the continental shelf. Modern observations indicate a recent reduction of AABW production, in response to ocean freshening and warming, and changes in the icescape along the continental shelves. However, the response of AABW formation to past climate forcing is uncertain, due to a paucity of suitable proxy records. Here we use authigenic Mn measured in two sediment cores (2600 m depth), to track the delivery of well-oxygenated DSW on the continental slope near Adélie Land, East Antarctica. We find increasing concentrations of aMn early during the last and penultimate deglaciations, coincident with increases in Th-normalised opal and excess Ba fluxes. We infer that the formation of DSW was reduced during glacial maxima, and was reinitiated when sea-ice retreated and productivity ramped up early in the Southern Hemisphere deglacial sequence. Our results have implications for deep ocean circulation during glacial periods and suggest a tight coupling between ocean-ice and climate during deglacial warming.

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Multi-proxy investigations of a Late Quaternary sedimentary record from the continental slope in the Amundsen Sea, West Antarctica: Implications for oceanic forcing of ice-sheet changes

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The marine-based West Antarctic Ice Sheet (WAIS) is considered as the most vulnerable part of the Antarctic Ice Sheet. Far-field data together with results from numerical models and a study on sub-glacial sediments from the modern ice-sheet base suggest that the WAIS collapsed at least once, and possibly even multiple times, during warm interglacial periods of the Late Quaternary. Moreover, modern observations combined with modelling experiments predict that current thinning, flow acceleration and retreat of ice streams draining into the Amundsen Sea Embayment (ASE), forming the so-called "weak underbelly" of the WAIS, may lead to major draw-down of their drainage basins in the future and potentially trigger a WAIS collapse. Sub-ice shelf melting caused by the upwelling of relatively warm Circumpolar Deep Water (CDW) onto the ASE shelf has been identified as the main driver of the present mass loss of glaciers feeding into ice shelves fringing the ASE coast. This sub-ice shelf melting, which reduces the buttressing effect of the ice shelves, is held responsible for most of Antarctica's contribution to the ongoing global sea-level rise. The crucial role of ocean forcing for ice-sheet dynamics has been furthermore corroborated by results from ice-sheet/ice-shelf models indicating that this mechanism was the most important driver of WAIS retreat that took place at the end of Late Quaternary glacial periods.

Here we present results of multi-proxy analyses on a sediment core recovered from the ASE continental slope which were carried out to test the hypothesis of oceanic forcing of interglacial WAIS retreat. The site is located on a seamount, and therefore the retrieved pelagic sedimentary sequence is condensed, probably because turbidity currents originating from the adjacent ASE shelf bypassed the seamount, while bottom currents deposited contourites on the deeper continental rise. Another consequence of the shallow site location at a water depth of just 2077 m is its position above the Calcite Compensation Depth (CCD). Thus, the record consists of bioturbated to massive, partly foraminifera-rich sandy muds that contain sufficient planktic and benthic calcareous foraminifera throughout for applying oxygen isotope (δ18O) stratigraphy. Palaeomagnetic measurements identified the Brunhes-Matuyama chron boundary (780 ka) between 2.82 m and 2.87 m core depth. Based on this age constraint, the foraminiferal δ18O data provide evidence for continuous sediment deposition from ca. 800 ka well into the Holocene.

Contents of calcium carbonate (CaCO3) were analysed on discrete bulk samples and barium/titanium (Ba/Ti) ratios were determined by XRF-scanning on the half cores as proxies for productivity. The

CaCO3 contents show that the core site was located above the CCD throughout the last 800 ka, with the Ba/Ti ratios, which reflect the content of biogenic barium as the most reliable palaeo-productivity proxy in Antarctic margin sediments, documenting that the CaCO3 contents were not significantly overprinted by dissolution. In general, biological productivity mirrors glacial-interglacial cyclicity, with CaCO3 contents and Ba/Ti ratios being higher during interglacials than during glacials, probably as a result of prolonged open-water seasons.

Stable carbon isotope data (δ13C) obtained from shells of the epifaunal benthic foraminifer Cibidcides cf. wuellerstorfi maintain relatively high values throughout the last 800 ka, indicating continuous CDW upwelling along the ASE margin during glacial-interglacial cycles. The benthic δ13C data show slightly increased interglacial values and thus reveal that CDW upwelling was slightly intensified during warm periods, probably driving WAIS retreat during these times. This conclusion is consistent with trace metal data (magnesium/calcium ratios, boron/calcium ratios, etc.) analysed on Cib. cf. wuellerstorfi shells that suggest enhanced CDW upwelling and/or upwelling of warmer CDW during interglacials.

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Late Quaternary carbonate dissolution cycle recorded in southern Drake Passage sediments

Jae Il Lee, Kyu-Cheul Yoo, Sunghan Kim, Min Kyung Lee, Heung Soo Moon, Yong Hee Park

Changes in deep sea carbonate chemistry might have played an important role in controlling the glacial-interglacial variation in atmospheric carbon dioxide (pCO2) concentration. However, contribution of deep ocean to glacial-interglacial pCO2 variation is still elusive, partly due to deficiency of carbonate data in critical regions such as those proximal to the source of global deep water. Here we present the carbonate content of six gravity cores from 2710 to 4090 m water depths of the southern Drake Passage (SDP). A gravity core from 2710 m contains carbonate of 16 to 63%, and shows high-carbonate interglacial and low-carbonate glacial pattern, reflecting higher primary carbonate productivity during interglacial periods. The other SDP cores from deeper water depths, however, contain much lower carbonate of 0 to 26%, and are characterized by virtually no carbonate during interglacial periods for the last ~800 kyr. This difference in glacial-interglacial carbonate variability pattern among different water depths suggests that dissolution of carbonate on the seafloor has been more intense during interglacial periods than glacial periods during the late Quaternary in the SDP. We interpret this is due to highly corrosive nature of interglacial deep water originated from the Weddell Sea. Oceans bathed by the deep water originated from the Weddell Sea and probably from the Antarctic margins should have been affected by the corrosive interglacial deep water, and the so-called 'Pacific-type' carbonate pattern of low carbonate interglacial and high carbonate glacial periods can be made in those regions. This study emphasizes the active role of Antarctic-sourced deep water, especially during interglacial periods, in controlling deep sea carbonate saturation state. Wider shelf area and more extensive ice shelves in interglacial periods compared with glacial periods might have facilitated the production of corrosive deep water in the Antarctic margin.

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Iceberg Alley and South Falkland Slope Ice and Ocean Dynamics

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We will present first results from IODP-Expedition 382 (Iceberg Alley). We investigate the long-term climate history of Antarctica, seeking to understand how polar ice sheets responded to changes in atmospheric CO2 in the past and how ice sheet evolution influenced global sea level. Four sites in the Scotia Sea, east of the Antarctic Peninsula, will provide the first deep drillings in this region of the Southern Ocean. We hope to recover over 600 m of late Neogene sediment that will be used to reconstruct the past history and variability in Antarctic Ice Sheet (AIS) mass loss, as well as associated changes in oceanic and atmospheric circulation.

Specifically, we expect to deliver the first spatially and temporally integrated record of icebergs flux from "Iceberg Alley", the main pathway by which icebergs are calved from the margin of the AIS and travel equator-ward into warmer waters of the Antarctic Circumpolar Current. In particular, we will characterize the magnitude of iceberg flux during key times of AIS evolution: a) the middle Miocene glacial intensification of the East Antarctic Ice Sheet; b) the mid-Pliocene warm interval; c) the late Pliocene glacial expansion of the West Antarctic Ice Sheet; d) the mid-Pleistocene transition; and e) during the warm interglacials and glacial terminations of the last 800 kyr. We will use the geochemical provenance of iceberg-rafted detritus and other glacially-eroded material to determine regional sources of AIS mass loss in this region, study the distribution and history of land-based versus marine-based "ice-sheets" around the continent over time, and explore the links between AIS variability and global sea level.

By comparing N-S variations across the Scotia Sea, Expedition 382 will also deliver critical information on how climate changes in the Southern Ocean affect ocean circulation through the Drake Passage, meridional overturning in the region, water-mass production, CO2 transfer via wind-induced upwelling, sea-ice variability, bottom water outflow from the Weddell Sea, Antarctic weathering inputs, and changes in oceanic and atmospheric fronts in the vicinity of the Antarctic Circumpolar Current.

Comparing changes in dust proxy records between the Scotia Sea and Antarctic ice cores will provide a detailed reconstruction of changes in the Southern Hemisphere westerlies on millennial and orbital time scales for the last 800 kyr. Extending the ocean dust record beyond 800 kyr will help to evaluate climate-dust couplings since the Pliocene, the potential role of dust in iron fertilization and atmospheric CO2 drawdown during glacials, and whether dust input to Antarctica played a role in the mid-Pleistocene transition.

The scientific objective of the Falkland/Malvinas sites is to reconstruct and understand how ocean circulation and intermediate water formation responds to changes in climate with a special focus on the connectivity between the Atlantic and Pacific basins. The South Falkland Slope Drift, a contourite drift on the Falkland Margin deposited between 400 to 2000 m water depth, is ideally situated to monitor millennial to orbital scale variability in the export of Antarctic Intermediate Water beneath the Sub-Antarctic Front over at least the last 1 Ma. We anticipate that these sites will yield a wide array of paleoceanographic records that can be used to interpret past changes in the density structure of the Atlantic sector of the Southern Ocean and track the migration of the SubAntarctic

Front. We expect the cored sediments to capture significant climate episodes including: (a) the most recent "warm interglacials" of the late Pleistocene; (b) the mid-Pleistocene transition, when δ18O records shifted from dominantly 41 to 100 kyr periodicity; and possibly (c) the mid-Pliocene warm interval, a past warm interval which is often invoked as the best analogue for possible future climate change.

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Continuous late Miocene to present records on West Antarctic Ice Sheet dynamics: Summary of IODP Expedition 379 to the Amundsen Sea

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The Amundsen Sea sector of Antarctica has long been considered the most vulnerable part of the West Antarctic Ice Sheet (WAIS) because of the great water depth at the grounding line, incursion of warm Circumpolar Deep Water, and the lack of substantial buttressing ice shelves. Ice flowing into the Amundsen Sea embayment is currently undergoing the most rapid changes of any sector of the Antarctic ice sheets, including substantial grounding line retreat over recent decades as observed from satellite data. Recent models suggest that a threshold leading to collapse of WAIS in this sector may have been passed already and that much of the WAIS could be lost even under relatively moderate greenhouse gas emission scenarios. Drill cores from the Amundsen Sea provide tests of several key questions about controls on ice sheet stability. Since the Amundsen Sea drainage basin currently has the largest negative mass balance of ice of anywhere in Antarctica, geological tests of ice-sheet stability in this region are thus of prime interest to future predictions.
IODP Expedition 379 successfully drilled two sites on the continental rise of the Amundsen Sea in January-March 2019, despite operational difficulties. Site U1532 is located on a large sediment drift and penetrated to a depth of 794 mbsf with 90% core recovery. Nearly continuous cores were collected from the Pleistocene down through an expanded Pliocene–uppermost Miocene sequence.
Site U1533 was drilled to a depth of 383 mbsf (70% core recovery) into a more condensed sequence down to the upper Miocene on the lowermost flank of the same sediment drift, recovering a complete Pleistocene–uppermost Pliocene composite section and a correlative, but more condensed, Pliocene section to that recovered at Site U1532. The cores of both sites contain unique records to study the cyclicity of ice sheet advance and retreat processes as well as ocean-bottom circulation and water mass changes. In particular, Site U1532 revealed distinct cyclic Pliocene lithofacies alternations with an excellent paleomagnetic record, which will be suitable for high-resolution, sub-orbital scale climate change studies of the previously sparsely sampled Pacific sector of the West Antarctic margin. Coarse-grained sediments, interpreted as ice-rafted debris (IRD), were identified throughout all time periods recovered. Cyclicity interpreted to represent relatively warmer periods, variably characterized by higher microfossil abundance and higher counts of IRD, alternating with colder periods, characterized by dominantly gray laminated terrigenous muds, is a dominant feature of the cores. Initial comparison of these cycles to published records from the region suggests that those units interpreted as recording warmer time intervals in the core relate to interglacial periods and those units interpreted as being deposited during colder periods tie to glacial periods. The association of lithological facies at both sites predominantly reflects the interplay of downslope and contouritic sediment transport with phases of relatively more pelagic sediment input. Despite the lack of drill cores from the shelf, our records from the continental rise reveal the timing of glacial advances onto the shelf and, thus, the expansion of a continent-wide ice sheet in West Antarctica at least back to the late Miocene.

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Paleoceanographic changes in the Southern Ocean off Elephant Island since the Last Glacial Maximum

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Three sediment cores were collected from the Southern Ocean off Elephant Island by R/V Yuzhmorgeologiya during 2003/2004 Korea Antarctic Research Program. The core site is ideal for reconstructing paleoceanographic changes in response to glacial retreat since the last glacial period because of its location. In order to reveal how the oceanographic changes are associated with ice sheet/sea ice changes since the last glacial period, we measured geochemical proxies, bulk nitrogen isotope, physical properties, and sediment grain size from all cores. Surface water productivity was dominated by diatom production. Surface water productivity was low during the last glacial period under extensive sea ice conditions and became high during the interglacial period under more open ocean conditions. Apparently, surface water productivity seems to be controlled by sea ice concentration. However, bulk nitrogen isotope, nutrient utilization proxy, showed decreased nutrient utilization with increased surface water productivity and increased utilization with decreased surface water productivity, indicating that surface water productivity in the core site is controlled by nutrient availability in association with changes in sea ice extent. Our result indicates that the surface current system, Antarctic Circumpolar Current, is closely related to changes in cryosphere and oceanographic condition. In addition, our result showed surface water productivity decrease during mid to late Holocene with decreasing nutrient utilization, suggesting deepening of mixed layer depth with intensifying surface current. At the same time, sortable silt also supported stronger bottom current intensity. During this time period atmospheric pCO2 in the Antarctic ice core was also increasing. This suggests the strong coupling of cryosphere-ocean-atmosphere in the Southern Ocean off Elephant Island.

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Ice-shelf and sea-ice dynamics: the biomarker perspective

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Evaluating the impact of sea ice and ocean temperature changes on ice-shelf stability is a crucial aspect for the identification of ocean-cryosphere interactions and the response of Antarctic ice-sheets to climate variability. The role of sea ice in ice-sheet proximal environments, however, remains poorly constrained as the application of diatom assemblages in heavily (summer) sea ice covered coastal areas is often hampered by silica dissolution. Highly branched isoprenoids (HBIs) provide a promising tool to overcome this gap. Biomarker analyses focusing on the di-unsaturated HBI termed IPSO25 (Ice Proxy for the Southern Ocean with 25 carbon atoms; Belt et al., 2016), related tri-unsaturated HBIs and phytosterols as well as the application of GDGTs as paleothermometer provide a valuable toolbox for assessing paleoenvironmental conditions in ice-proximal areas. Here, we present preliminary biomarker data obtained from sediment cores collected in the Bransfield Strait, the Amundsen Sea and the Weddell Sea. The data reveal distinct fluctuations in sea ice coverage and primary productivity during the last deglacial(s), which, through consideration of sedimentological data alongside these biomarker records, can be linked to phases of retreating and advancing glacial ice.

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Antarctic-driven Pliocene global sea-level variability

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Earth is rapidly heading towards a climate that was last experienced more than three million years ago (Ma) during the "mid-Pliocene warm period" (MPWP). During this time, global sea levels oscillated in response to orbital forcing with peak global mean sea level (GMSL) estimated at ~20 m above present according at previous studies using a range of approaches. These studies imply highly sensitive polar regions, under atmospheric carbon dioxide (pCO2) concentrations of ~400 ppm, resulting in melting of the Greenland (GIS), West Antarctic (WAIS) and marine based sectors of the East Antarctic ice sheets (EAIS).

A new sea-level record of glacial-interglacial variability for the mid- to late Pliocene, ~3.3 - 2.5 Ma, named PlioSeaNZ, has been developed from continuous, well-dated, highly-resolved shallow-marine sediment core and outcrop from Whanganui Basin, New Zealand. Water depth changes are reconstructed using a novel depth-dependent, sediment grain-size proxy, independent of the deep ocean oxygen isotope (δ18O) record for global ice volume. This is corrected for tectonic subsidence and subsequent compaction using a backstripping approach to determine the amplitude of relative sea-level (RSL) change. Glacio-isostatic adjustment (GIA) simulations of RSL change, show that the PlioSeaNZ record approximates eustatic sea level (ESL), which is GMSL unregistered to the centre of the Earth. While the amplitude of the PlioSeaNZ cycles cannot be registered to present day sea level, the individual cycles are unaffected by dynamic topography.

Our results provide new constraints for polar ice sheet and global sea-level variability during the MPWP and the late Pliocene, that are: (i) independent of estimates from δ18O stack and other geochemical proxies, and (ii) broadly consistent with AIS models that simulate a contribution of +13 - 17 m global sea-level rise above present. We note that because our record cannot be registered to present-day sea level, due to post-depositional tectonic uplift of Whanganui Basin, we cannot directly constrain the magnitude of peak Pliocene global sea level above present. Notwithstanding this, our results provide key insights into AIS sensitivity when Earth's climate equilibrates to ~400 ppm pCO2 concentration. Notably, that although ice sheet, ocean and continental geometries were subtlety different during the MPWP, the potential exists for complete loss of marine-based ice sheets, that will contribute up to 23 m global sea-level rise, if atmospheric CO2 remains above 400 ppm. If all the glacial-interglacial variability in the PlioSeaNZ record was above present day sea-level, then GMSL sea-level during the warmest mid-Pliocene interglacial was no more than +25 m, assuming the GIS melted synchronously.

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East Antarctic Ice Sheet evolution and paleoclimate of the Aurora Subglacial Basin since the Late Cretaceous: Proposed geologic drilling on the Sabrina Coast continental shelf

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The East Antarctic Ice Sheet (EAIS) contains ~19m of sea-level-equivalent ice and one of the largest marine-based catchments is the Aurora Subglacial Basin (ASB), which extends from the Gamburtsev Mountains to the coast and contains 3-5 meters of sea-level equivalent ice. Models indicate that Antarctica's ice sheets nucleated in the Gamburtsev Mountains, reached the Sabrina Coast before continental-scale ice sheets formed, and remained relatively sensitive to climate perturbations through the Cenozoic. However, these models are not currently constrained by ice-proximal geologic data and uncertainties remain regarding the timing, rates, spatial heterogeneity, and mechanisms of EAIS evolution.

High-resolution Sabrina Coast continental shelf seismic reflection data reveal a ~1200 m thick record of ASB catchment evolution and associated climate/oceanographic change during times when CO2 concentrations and temperatures were equal to and/or exceeded those expected with continued anthropogenic warming. Short piston cores reveal warm Cretaceous to Paleocene climates deteriorated by the early-to-middle Eocene and regional glaciers advanced to the coast. Between the middle Eocene and late Miocene, the region experienced ~12 meltwater-rich cross-shelf glacial advance/retreat cycles. Above a regional unconformity of late Miocene age, a ≤110 m veneer of glacial to glaciomarine sediments suggests some Plio-Pleistocene glacial variability and a shift in ice sheet thermal regime.

We propose a 60-day geologic drilling program on the Sabrina Coast continental shelf. This program tests fundamental hypotheses related to Cenozoic climate and EAIS evolution developed from deep-sea sediments, global CO2 estimates, and models. The exceptional Sabrina Coast record, though inherently discontinuous, offers: direct evidence of ice margin fluctuations and continental conditions, shallow access to older strata due to tilting and glacial erosion of overlying strata, as well as high sedimentation rates and shallow water depths, which favor carbonate macro- and microfossil preservation. The proposed drilling program will provide key constraints on the: 1) existence of warm high southern latitude climates during the late Mesozoic and early Cenozoic, 2) evolution of the EAIS in the ASB from the Paleogene to the last deglaciation, and 3) the evolution of regional

subglacial hydrology and its role in past glacial dynamics.

Two transects of primary and alternate sites (200-400 m deep holes; 400-600m water depth) can address Late Cretaceous through Neogene objectives and minimize Holocene cover. A broad range of dateable open marine, glaciomarine, and subglacial sediments are accessible by shallow (150-300m) drilling of dipping stratigraphy, which allows us to drill 700-800 m of the ~1300m thick sequence. Abundant seismic line crossings provide site selection flexibility that enables us to meet all scientific objectives. To maximize recovery, we propose to drill from an icebreaker with either a seabed drill or a modified mining rig with a diamond-bit wireline coring string, generally low weight-on-bit, and high RPMs; a self-supporting riser casing or reentry system would enable safe operations in challenging ice/sea state conditions. This accessible archive of past Antarctic climate and ice sheet history will provide data to improve ice sheet and climate model boundary conditions and outputs. This type of data-model integration is required to better understand the response of Antarctica's ice sheets to continued anthropogenic warming. Proposed drilling fits within the SCAR Past Antarctic Ice Sheet Dynamics (PAIS) program and objectives complement those of existing geophysical studies and future subglacial drilling programs.

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Proximal Aurora Basin records of glacial extent, subglacial hydrology, ice routing, and paleoenvironment: Keys to understanding climate sensitivity of the East Antarctic Ice Sheet

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Understanding of the formation and evolution of Antarctica's continental-scale ice sheets is critical for improving accuracy of future ice mass loss projections due to climate change. Knowledge of continental scale ice sheet evolution is limited by a dearth of ice-proximal records from continental shelves. Key evidence found in such records includes: ice-rafted debris that informs the presence of marine-terminating glaciers; erosional surfaces, tunnel valleys, and/or grounding zone wedges indicative of past grounded ice and increased ice volume relative to present; and marine sediments indicative of open water and reduced ice coverage relative. Offshore the Totten Glacier, on the Sabrina Coast, East Antarctica, seismic reflection images and piston cores provide evidence for past advances/retreats of marine terminating glacial systems in the Aurora Basin catchment over the past ~50 million years. Data indicate evidence of the first regional marine terminating glaciers in the Eocene followed by 12+ episodes of ice advance/retreat over the continental shelf between at least the middle Eocene to late Miocene. Sabrina Coast seismic data include evidence of large tunnel valleys rarely observed in Antarctic margin records, suggesting a temperate meltwater-rich glacial system in this catchment, similar to those hypothesized from geomorphic evidence in Antarctica's Dry Valleys. In contrast, Sabrina Coast data indicate that meltwater-poor outlet glaciers drained the Aurora Basin from the late Miocene to present. This switch to lower meltwater conditions suggests an increase in ice sheet size and stability by the late Miocene-early Pliocene, later than the traditionally accepted middle Miocene (~14 Ma). Future exploration of this climatically sensitive East Antarctic catchment should include additional seismic and coring studies closer to Totten Glacier and other key Aurora Basin outlet glaciers, including Vincennes Glacier, west of Law Dome. The preserved record of sediments on the Sabrina Coast continental shelf should be sampled at high-resolution through scientific drilling to confirm ages and paleoenvironments, which will enable understanding of processes potentially driving past glacial instability in the Aurora Basin, which at present contains 3-5 m of sealevel-equivalent ice.

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Insights into the Oligocene-Miocene transition at the Wilkes-Adelie Land margin

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The Integrated Ocean Drilling Program (IODP) at Site U1356 and Deep Sea Drilling Project (DSDP) at Site 269, recovered sediments from the Wilkes Land margin along a latitudinal depth transect. Site U1356 is dominated by contourite deposition from 33.6 Ma to the end of the Oligocene (around 24 Ma), when Mass Transport Deposits (MTDs) dominate the sedimentary section leading to the Mi -1 glacial expansion event. At Site U1356, the Oligocene to Miocene Transition (OMT; 24.2 to 23 Ma) coincides with the disappearance of MTDs and the start of turbidite and hemipelagic deposition that characterizes levee sedimentation of the early Miocene environment. Deposition at Site 269 is characterized by contour current deposition punctuated by periods with dominance of distal turbidites during the OMT. A new age model for the lower part of the Site 269 has been established based on the integration of new magnetostratigraphic data and microfossil biostratigraphy, including dynocyst and calcareous nannoplankton biostratigraphic constraints. Based on the new age model, Site 269 contains the sedimentary record from 24 to about 17 Ma, therefore recording the oceanic conditions during the period masked by the MTDs at the more proximal Site U1356. Both sites, preserve carbonate-rich intervals pointing to times when the site locations are bathed by warmer Circumpolar Deep Waters (CDW). Sediments from both sites provide an opportunity to reconstruct the paleoceanographic conditions off the Wilkes Land margin during the Oligocene-Miocene, which point to fundamental different oceanographic configuration from that of today in this sector of the Southern Ocean.

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Pre-site surveys and plans for deep geological drilling below the Ekström Ice Shelf (Sub-EIS-Obs): Linking East Antarctic slope and shelf stratigraphy

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Over the last Antarctic fieldwork seasons, pre-site seismic surveys have been undertaken in the Ekströmisen region of Dronning Maud Land with the primary objective to build a stratigraphic framework of the sub-ice-shelf sedimentary strata. These sediments overlie the Explora Wedge, a syn- or post-rift volcanic deposit, and their ages are expected to range from Late Mesozoic to Quaternary. We selected sites on new vibroseismic profiles for recovering short marine sediment cores through Hot Water Drill (HWD) holes in order to constrain the age ranges of the oldest and youngest sedimentary sequences. There is further potential for geological deep drilling with the support of international collaboration partners. Deep drilling would enable us to recover the sediments directly overlying the Explora Escarpment and thus reveal the geological nature of the Explora Wedge. We expect the overlying sedimentary sequences to unravel the Cainozoic history of the East Antarctic Ice Sheet (EAIS) and climate changes in this part of Antarctica, especially the waxing and waning of the EAIS during past glacial and interglacial periods and the effects of polar amplification during times of warmer climates. This knowledge will be crucial for predicting future EAIS variability and associated global sea-level changes.
Sampling the sub-ice shelf sea floor through HWD holes will provide a unique opportunity for interdisciplinary 'piggy-back' activities. Experiments and measurements for oceanography, sea-ice and ice-shelf physics, geophysics, geology, and biogeochemistry could be performed to investigate and characterise ocean-ice-sediment interactions and processes and to carry out ecosystem observations. During future campaigns, Autonomous Underwater Vehicles (AUV) with the power to operate under the ice shelf and analyse its cavity could be deployed through HWD holes, from a ship or from fast ice attached to the Ekström Ice Shelf. International partners are welcome to join discussions of the data and samples already collected and to contribute together with scientists of the ANDRILL Scientific Committee (ASC) to the preparation of an ICDP or IODP amphibious drilling proposal.

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20th Century dust influx to east Antarctica: Causes and contribution to radiative forcing

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Atmospheric dust has a significant influence on the global climate variability and change in radiative forcing of glacier systems. Paleo-dust records from Antarctic ice cores allow us to understand the past atmospheric dust concentrations and to evaluate the fluctuations in continental dust in changing climatic conditions.

Here we present a high-resolution ice core dust record from coastal Dronning Maud Land (71°20'S, 11°35'E) to understand dust flux variability, its causes and consequences in terms of contribution of radiative forcing to the last millennium climate variability over east Antarctica. Our investigation for such dramatic dust flux increase reveals that the increased aridity and wind speed over the Southern South America, a potential dust source to Antarctica, has caused a massive increase in dust production since the 1980s. The dust flux variability in Southern Hemisphere during the last century is concomitant with in-phase relationship between El-Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillations (PDO), which influenced the spatial distribution of global wet-dry phase (precipitation pattern). Our estimate of radiative forcing corresponding to the dust flux increase using a radiative transfer model yields nearly 30% increase in aerosol forcing which in turn 40% decrease in atmospheric cooling rate. This has resulted a net atmospheric warming in coastal Dronning Maud Land region during the late 20th century.

The present study would help to understand the past climate variability by providing radiative forcing input to the climate models as well as improve our current knowledge about the role of dust in contributing to Southern Hemisphere warming during the last millennium.

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Volcanic impact on chlorine chemistry: Evidence from perchlorate in Antarctic and Arctic ice cores

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Recent research has found significantly increased perchlorate concentrations in Arctic ice cores following several powerful volcanic eruptions that occurred in the last two centuries. The increase in perchlorate deposition is hypothesized to result from enhanced formation of perchlorate in the atmosphere, likely in the stratosphere. One implication of this hypothesis is that an atmospheric perchlorate response to volcanic perturbation would not be restricted to the Northern Hemisphere and that perchlorate in Antarctic snow would also be elevated following volcanic eruptions. We measured perchlorate in selected sections of an Antarctic ice core containing the sulfate fallout of several well-known volcanic signals (the 1815 Tambora eruption, the unknown 1809 event, and an eruption in 1458). We found that perchlorate concentrations during these volcanic events to be significantly elevated over that in snow deposited several years before or after the volcanic sulfate fallout. This preliminary finding of increased perchlorate in Antarctic snow following major eruptions supports the hypothesis that the volcanic impact on atmospheric chlorine chemistry leading to enhanced perchlorate is very likely a global phenomenon. The perchlorate response, however, appears to be different from that of sulfate in several aspects, including relative enrichment magnitude and precise timing of deposition. A systematic study with careful examination of high-resolution ice core perchlorate records is needed to better understand and characterize the impact of volcanic eruptions on atmospheric chlorine chemistry.

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Impact of photochemical reactions on atmospheric particles in Antarctica

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Changes in Antarctica ice sheets and ice shelves are of primary concern for the regional and global climate. The chemical process of aerosol in the West Antarctic region can take part in local global warming. Rather than being inert, snow is highly active, with snowpack impurities being photolysed to release reactive trace gasses such as OH, NO/NO2 and O3 into the troposphere. The impact of solar radiation, enhanced by O3 depletion, creates the optimal conditions for heterogeneous gas-to-particle reaction, modifying the chemical and physical properties of aerosols substantially. Using microscopic and chemical speciation of individual aerosol particles by scanning transmission X-ray microscopy with near edge X-ray absorption fine structure spectroscopy (STXM/NEXAFS) combined with computer controlled scanning microscopy (CCSEM) with energy dispersive X-ray (EDX) microanalysis, we present evidence of atmospheric processing. This work presents trends of aerosol transformation in the western of Antarctica and illustrates the ability of snowpack photochemistry to affect particle composition which in turn may affect aerosol light scattering. A substantial fraction of internally mixed particles with NaCl cores and nitrate coatings were observed in individual aerosols sampled. The scattering efficiency of sea salt particles may decrease as a consequence of the external nitrate covering since the hygroscopicity of a mixed nitrate-salt particle is weak. Incorporation of the nitrate over the sea salt aerosols should be considered in future studies of climate models to assess the local aerosol radiative effects. Farther, the organic contain on aerosols describe an interesting climate behavior and paint one of the significant fractions of tropospheric particles. Assuming that the aerosols at Criosfera 1 are primarily marine in origin, fresh aerosols should contain significant organic matter. However, the samples revealed a low organic contain what could be driven by the oxidizing process, during the transport of the coast to center of continent. The photochemistry driven by locations with elevated levels of NOx result in accumulation of tropospheric ozone that can double the background concentration. As a consequence of the elevated OH concentration above the snowpack (found at South Pole) and by the ozone oxidation caused process, almost all organic aerosol found in our samples should be impacted and oxidized during the transport to the Antarctica continent. Oxidation reactions (primarily by the hydroxyl radical) of organic species can dramatically change the reactivity, amount, properties and hence the ultimate impacts of atmospheric particles, as the type of aging, with the potential to affect the optical properties, hygroscopicity, and cloud condensation nucleus activity of particulate matter.

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Potential for Extremely Old Ice at Dome A

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The oldest currently existing ice core is Dome C, which goes back 800 ka. Presently, there is a search for an ice core drill site that could span the mid-Pleistocene transition (MPT, ~700-1200 ka). Here, I predict that ice cores spanning the MPT- and potentially much older- may be found within deep narrow valleys under Dome A in East Antarctica. Dome A overlies the Gamburtsev Subglacial Mountains, a rugged mountain range containing an arborescent valley network and numerous cirques preserved since the very early stages of glaciation. Traditionally, it has been assumed that rough basal topography is bad for ice cores, as it encourages complex deformation of the basal ice.
However, rather than increasing basal deformation, deep valleys underneath an ice divide generate stress shadows in which deformation is extremely slow. Large-scale thermomechanical modeling indicates that conditions are good for stagnant ice to form along a ~100 km long ice divide extending south from Dome A. Small-scale Full Stokes modeling confirms that narrow valleys can produce stress shadows in which extremely old ice can be preserved.
Existing radar lines are sufficient to prove that such valleys exist, but are too widely spaced to characterize their geometry in detail. A closely-spaced survey around the divide would be needed before a specific valley could be chosen for drilling. The main weakness in this hypothesis is the possibility that the ice divide may have migrated over geologic time, but the topographic control provided by the mountains may limit the range of divide migration.

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Accelerated chemical reactions in the frozen environments

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Most of the fresh water on earth exists in the frozen state but chemical reactions in frozen solutions have been not much investigated. We have investigated several homogeneous and heterogeneous chemical reactions in frozen solutions, especially those which have environmental significance and found that many environmental chemical reactions taking place in frozen solutions are significantly different compared to aqueous counterparts. The studied reactions include the photochemical and chemical dissolution of metal oxides, the reductive transformation of hexavalent chromium and bromate, the photooxidation of iodide, and the humification of phenolic compounds. All the above environmental redox chemical reactions occurring in ice (frozen solutions) were markedly accelerated while their aqueous counterpart reactions proceeded very slowly. Such phenomena can be related with the freezing-induced concentration of reactants in the unfrozen ice grain boundaries that should exist between ice crystals. The observed accelerated processes in frozen media may have significant effects on the chemical transformation processes in the cold environment such as polar region, upper atmosphere, and frozen soil.

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Spontaneous reactions in cryogenic ice films. Enhanced dissociation of weak acids driven by mobile proton's entropy in ice

Youngwook Park, Sunghwan Shin, Heon Kang †

It has been conceived that chemical reactions are extremely difficult to occur in ice at very low temperature, where atoms and molecules are frozen in position with minimal thermal energy and entropy. Contrary to this general behavior, certain weak acids including fluoroacetic acids dissociate spontaneously and more efficiently in cryogenic ice than in aqueous solution at room temperaure. The enhanced reactivity of weak acids is an unexpected consequence of proton transfer equilibrium in ice. The configurational entropy of highly mobile protons in ice shifts the acid dissociation equilibrium forward. Although this entropy is generated in the solid phase water, it is comparatively large in magnitude with the entropies of water vaporization and acid dissociation reactions in aqueous phase. This themodynamic force is expected to underlie a range of proton transfer reactions in ice environments.

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On the possibility to restore the stable water isotope climatic signal from the highly disturbed section of old (0.4-1.2 Ma) Vostok ice

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Basal part of Vostok (central Antarctica) ice core (3310-3539 m) consists of ice that was formed between 0.4 and 1.2 million years ago, as was defined by 3 independent methods of absolute dating (Lipenkov et al., 2019). This ice interval is characterized by unconformed layer sequence due to macro- and micro-scale folding of ice layers.

In this work we present a new high-resolution (10 cm) stable water isotope time-series for 0.4-1.2 million years ago and analyze the preservation of the initial climatic signal in this highly disturbed record. We show that MIS12-MIS16 section of the old ice (0.42-0.65 Myrs ago) is highly deformed by large-scale ice folding with a possibility of partial restoration of the initial signal by "unfolding" of the corresponding intervals of the isotopic record. MIS17 and MIS18 sections (0.65-0.75 Myrs ago) are preserved better, although the amplitude of the isotopic signal is reduced by the micro-scale folding with relatively weak contribution of molecular diffusion. In MIS19-MIS28 sections (0.75-1.0 Myrs ago) the signal amplitude strongly reduces due to micro-folding and mixing followed by strong molecular diffusion. Finally, in the oldest part of the record (1.0-1.2 Myrs ago) the isotopic variability related to the main climatic cycle (40-100 kyrs) is virtually erased and cannot be restored.

It is important to note that it is the combined impact of layer folding and molecular diffusion that is responsible for the observed disturbance of the isotopic signal. The folding and mixing of the layer reduce the period and amplitude of the ice stable water isotope variability leaving it more vulnerable to the molecular diffusion.

This work was supported by Russian Science Foundation, grant 18-17-00110.

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Inhomogeneous greenhouse gas concentration distributions due to snow density layer in the firn at Styx, Antarctica

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With Antarctic shallow ice cores, greenhouse gas emission records by human activity may be well reconstructed. In this context, it is crucial to understand the processes of air trapping in the shallow snow depth and how they affect the greenhouse gas concentrations in the bubbles.

In the top unconsolidated snow layer (firn), air is mixed by diffusion and convection. Atmospheric air is gradually trapped in closed pores along with depth increase in the firn. However, on small depth scales (e.g., mm or cm), the mean air ages in the bubbles at certain depth intervals can be variable due to difference in mean depth of air trap. Consequently, gas concentration can be also variable on mm or cm scales given that atmospheric concentration changes with time. Greenhouse gas concentrations in deep ice cores often reveal inhomogeneous distribution on cm scale, which might be due to the variable air trap history associated with snow density variations in the firn. In order to quantitatively test this idea, we analyzed greenhouse gas concentrations in different density layers in the firn ice. The density data on mm-scale were previously obtained from high-resolution X-ray measurements (Jang et al., in review). In general, low (high) gas concentrations were observed in the high-density (low-density) layers on cm scale. We interpret that air is trapped earlier in the high density layers than in the low density ones. Alternatively, however, low density layers with high open porosity can be highly contaminated by storage air with high greenhouse gas concentration because part of the open pores become closed during ice storage. To tell the two processes, we compared the greenhouse gas (CO2, CH4 and N2O) concentrations in the closed bubbles with those in the firn air (originally in open pores during drilling time). Our preliminary data indicate that the alteration by storage air may not be significant in some high-density layers, and may allow us better constrain the process of inhomogeneous greenhouse gas distributions in deep ice cores. Using atmospheric history of the greenhouse gas concentration changes and the depth-ice age profile, we may also quantitatively estimate the depths where the air is trapped in the firn ice.

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Session16: Significance of Antarctic Inland Freshwater Bodies - Revealing Past Processes and Projecting Responses to Change

New step forward in understanding Antarctic subglacial environment

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Nowadays conditions beneath Antarctic Ice Sheet are known mainly due to indirect methods of geophysical remote sensing, and there is no single framework for interpreting these data. To date, only a handful of studies have successfully recovered bedrock samples from beneath Antarctic ice sheet because drilling operations are complicated by extremely low temperature at the surface of, and within Antarctic Ice Sheet, and by ice flow, the absence of roads and infrastructures, storms, winds, snowfalls. Nevertheless, borehole drilling is still considered as the only one valid method to study Antarctic subglacial environment.

To recover subglacial bedrock samples in Antarctica, a new, modified version of the cable-suspended Ice and Bedrock Electromechanical Drill – IBED – have been developed in Jilin University and transported to Chinese Zhongshan Station in the Larsemann Hills, East Antarctica in November 2018. The developed drilling facilities are divided into two groups: those associated with the movable drilling shelter with 11-m-high mast and those associated with the movable workshop. In December 2018 – January 2019 drilling facilities were assembled at the ice sheet edge and preliminary tested. Then movable drilling shelter and movable workshop were transported to the tested site, about 12 km south from Zhongshan Station. The site was chosen in the near-coast area where subglacial topography is tracked to the highest point. The top of the subglacial hill is about 100 m higher than sea level ensuring dry, frozen-bed conditions in order to avoid contaminating the subglacial hydrologic environment.

Drilling was started at the very end of January, 2019 using bottom reverse circulation with fuel Jet A1; the average daily production was near 20 m/day. At 10th February, the borehole reached bedrock at the depth of 198 m. Drilling of the glacier ice and debris-rich ice rocks was carried out by the same construction of IBED electromechanical drill. The only difference concerned the type of the drilling bit: instead of a toothed coring bit with high-speed steel cutters, custom-built polycrystalline diamond compact drill bit has been used to drill through debris-containing ice. Entrained debris consisted predominantly of fine-grained yellow-colored inclusions, mainly silt, with some sand. After attempt to continue drilling with the ice-coring drill had proved fruitless, the lower part of IBED electromechanical drill was modified to accept a diamond rock-drilling bit in order to penetrate the rock substrate under the ice. The ice-chips section was removed along with the large diameter core barrel and replaced with a weighted drive section, chamber for gravity separation of the rock cuttings and small diameter, diamond-tipped core barrel. A 7-cm long rock core with 41-mm in diameter was recovered using a standard toothed impregnated diamond bit before drilling was terminated. Unfortunately, another attempt was not made because logistics forced an end to the camp. The bedrock core is characterized by about approximately 50 % ice content and by typical structures and textures of permafrost. Mineral materials included yellow supposedly metamorphosed gneiss.

The final goal of the project is to drill the hole in the northern part of Gamburtsev Subglacial Mountains, located in the central part of East Antarctica. Subglacial mountains have become the subject of great scientific interest because the mechanism driving the uplift of the range, which resembles younger mountain ranges in shape, in the middle of the old Antarctic Plate is unknown.

The first step of the project, field tests of the drilling equipment, have been succeeded, and drilling for bedrock on the Gamburtsev Subglacial Mountains is planned as soon as full financial and logistical support is obtained for the project.

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Surface Water-Groundwater Interactions in Two Small Lakes in Barton Peninsula, King George Island, Antarctica

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Surface water-groundwater interaction is an important component of water cycle and can have significant impacts on ecosystems in Antarctica. However, this important aspect has largely been overlooked; particularly, the contribution of groundwater has rarely been studied. This study investigated surface water-groundwater interactions in two small lakes (named as "Lake A" and "Lake B") near King Sejong Station in King George Island, Antarctica, during summer seasons of 2018 and 2019, by measuring groundwater flux and hydraulic head differences between lake and groundwater levels. The groundwater flux was measured using seepage meters installed in lake bottoms and the hydraulic head differences were measured using piezometers installed within and around the lakes. The results showed that "Lake A" was a gaining system in the early period of January 2018, but for the most period of January 2018 and the entire period of January-February 2019, it was a losing system. The measured groundwater flux was between 2.7x10^-9 m/s (influx from groundwater to surface water) and -1.0x10^-7 m/s (outflux from surface water to groundwater), indicating that groundwater-surface water interaction in this lake is very dynamic.

On the other hand, in "Lake B", groundwater and lake levels were relatively steady, and they indicated that the lake is a gaining system. The groundwater flux measured in "Lake B" was between 9.5x10^-10 m/s and 1.1x10^-8 m/s. The results also showed that the groundwater flux was proportional to the hydraulic head difference between the lake and groundwater levels. To the best of our knowledge, this is the first study that directly measured the groundwater flux into/out of Antarctic lakes and compared it to the hydraulic head difference between lake and groundwater levels. The approach used in this study can be useful to evaluate the contribution of groundwater component in Antarctic lakes and the role of groundwater in inland water ecosystems of Antarctica.
This study was funded by Korea Polar Research Institute (PE18090) and the Polar Academic Program (PE18900) of the Korea Polar Research Institute.

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The subglacial hydrology of the Ellsworth-Whitmore Mountains West Antarctica: newly identified subglacial lakes and the stability of water flow since the Mid-Pleistocene

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There is a well-developed subglacial hydrological network across the Antarctic continent (Wright et al., 2012; Fricker et al., 2014) and in places it is highly dynamic (Fricker et al., 2007). This is important because the subglacial water plays a fundamental role in controlling ice flow.
We aim to characterize the subglacial hydrology system in the Ellsworth subglacial highlands, West Antarctica, and assess the sensitivity of the flow routing under different ice sheet configurations. We are doing this so that we can better understand the regional setting of the various subglacial lakes in this area, including the recently discovered Lago Subglacial CECS (SLC; Rivera et al., 2015).
Knowledge of the source area for water in the lake as well as any potential drainage directions will help us determine the stability of the lake over recent and glacial-interglacial timescales. To understand the modern hydrological system, we use a range of available data (e.g., radar, Cryosat-2 ice surface DEM data); firstly, for calculating the hydropotential; and secondly, for determining the flow routing within Ellsworth-Whitmore Mountains (EWM) terrain. We then extend this approach to assess how the subglacial hydrological system responds to changing ice conditions (e.g., during glacial-interglacial cycles) where the ice extent, thickness, surface slopes and divides all evolve. To do this we use ice sheet model output (Pollard and DeConto, 2012) for snapshots of ice geometry relating to the last 150 k yr within which time period significant changes in ice conditions have been experienced.
We also conduct a broader analysis of the presence of subglacial water bodies in the region surrounding Lago Subglacial CECs. We identify ca. 23 new subglacial lakes by means of Radio Echo Sounding in the head of the subglacial basins underneath the ice divide of Pine Island Glacier (PIG), Rutford Ice Stream (RIS) and Institute Ice Stream (IIS) near Subglacial Lake Ellsworth and CECS. Analysis of present subglacial hydrological conditions suggest many of these subglacial lakes are connected in a bigger subglacial hydrological network, but some are not. Modelling of the past configurations of subglacial hydrological conditions (e.g. during the Mid-Pleistocene), using hydropotential from simulations, shows both spatial and temporal evolution of this subglacial hydrological network and indicates that in some areas water flow has reversed (e.g., RIS from Weddell Sea toward Amundsen Sea sector) but in other areas with isolated subglacial lakes, e.g. SLC, water conditions have remained largely static since the Mid-Pleistocene.
The findings of this work will improve our understanding of the subglacial hydrology of the EWM, and will be used to inform future subglacial lake access experiments in the EWM and in particular to Lago Subglacial CECS.

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Chemical Weathering and Meltwater Sources in Mercer Subglacial Lake, West Antarctica

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The Antarctic subglacial environment is now understood to support microbial life, and active subglacial hydrologic systems beneath the West Antarctic Ice Sheet (WAIS) supply solutes to the Southern Ocean. Geophysical and remote sensing observations have identified a large number of hydraulically isolated subglacial lakes of various sizes, active flow-through systems of lakes and streams, vast "swamps," and groundwater-like systems. The hydrologic diversity of these systems means they also have different water residence times, water-rock ratios, basal geology, and biological processes, all of which likely lead to a diversity of geochemistries. To date, few subglacial aquatic environments have been directly sampled in a clean fashion, and the geochemistry of these systems range from fresh, low salinity waters in Whillans Subglacial Lake, West Antarctica to a hypersaline brine under Taylor Glacier in the McMurdo Dry Valleys. The geochemistry of these aquatic environments is important, as the microbial communities are inextricably linked to the available solutes, and these microbes in turn mediate chemical weathering processes under the ice. Additionally, water in the active subglacial hydrologic network under WAIS ultimately reaches the Southern Ocean at the grounding zone, potentially delivering important nutrients and stimulating primary production.

As part of the integrated Subglacial Antarctic Lakes Scientific Access (SALSA) project, we sampled the water column of Mercer Subglacial Lake, under Mercer Ice Stream, West Antarctica, using clean entry techniques during nine days of borehole operations beginning on 24 December, 2018. The sources of solutes and meltwater to the lake were examined using a variety of geochemical constituents, as well as noble gases and their isotopes. 87Sr/86Sr was measured to determine which mineral phases are undergoing weathering and the type of aluminosilicate weathering occurring in these environments, and Ge/Si ratios were used to provide additional information on the balance of incongruent weathering of primary minerals and from the dissolution of secondary clay minerals. Noble gases (He, Ne, Ar, Kr, Xe) are sensitive tracers of glacial meltwater and yield data on the sources of meltwater beneath the ice streams. Isotopes of He and Ar reveal possible volcanic sources of gases to the subglacial environment and place constraints on the residence time of water in the subglacial system. We will relate these and other geochemical and gas measurements to the production and source of soluble species, sources of meltwater, and water residence time in Mercer Subglacial Lake and other subglacial environments.

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McMurdo Dry Valleys Stream Response to Annual Climate

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Streams integrate processes occurring within their catchments, and in the glacial meltwater streams of the McMurdo Dry Valleys (MDVs), Antarctica, flow magnitude and duration are direct reflections of the glacier conditions (i.e., albedo) and meteorological conditions that generate melt. MDV streams flow for 6-12 weeks during the austral summer. Each day they experience a flood wave of meltwater, the timing of which is dictated largely by the daily pattern of solar exposure and channel hydraulics. Stream flow increases its solute load as water moves downstream due to dissolution of surface salts early in the flow season, and rapid weathering of streambed sediments throughout the flow season. Here we evaluate the responses of streamflow dynamics and chemistry in response to climatic forcing over 20+ years of record in streams across the MDVs.

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Physical properties of a draining subglacial lake

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Research over the past decade has revealed a dynamic hydrological environment beneath the Antarctic ice sheet, with the ability to influence regional ice velocity, grounding-line stability, and fluxes of freshwater and micronutrients to the coastal environment. Hidden beneath 10s to 1000s of meters of ice, these enigmatic hydrological systems of interconnected lakes and streams are poorly understood, largely due to the short temporal window of the ice-surface observational record from which we infer hydrological dynamics and the lack of in situ instrumentation to directly sample lake properties. We present new airborne and satellite observations that extend the current record of active subglacial hydrology and explore the variability of Antarctic subglacial hydrological systems driven by the filling and draining of subglacial lakes. We then focus on Mercer Subglacial Lake beneath Mercer Ice Stream, West Antarctica, a lake directly accessed by the Subglacial Antarctic Lakes Scientific Access (SALSA) Project in January 2019 while it was in a draining phase, and examine the physical properties of the lake as it discharged water downstream toward the Ross Sea. Finally, we will discuss unique datasets collected as part of the SALSA Project, including a regional magnetotelluric survey and an in situ, fiber-optic-based continuous temperature record, that will provide new insight into the space and time variability of subglacial hydrological systems beneath Antarctica.

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Challenges and successes coring sediments from Mercer Subglacial Lake

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The rewards of retrieving sediment samples from subglacial environments include understanding the geologic history of overlying ice, observing biological processes in the sediment, measuring geophysical properties directly, and constraining environmental history. However, clean-access sampling of sediment from underneath ice sheets has proven challenging. Here, we describe efforts to collect the sediment-water interface and longer cores, including a novel borehole-operated free-fall gravity coring system, during the Subglacial Antarctic Lakes Scientific Access (SALSA) project. At Mercer Subglacial Lake in the 2018-2019 field season, the SALSA science team collected sediment cores with a both a modified multicorer and free-fall gravity corer, both of which were modified or designed for deployment in a 0.6 m diameter, 1092 m deep borehole with 15 m of in the lake cavity below the ice. The multicorer collected soft, fine-grained subglacial lake sediment cores 0.3-0.4 m in length and the free-fall gravity corer collected sediment cores of 0.97 and 1.78 m length. The multicorer uses a core catcher that is deployed upon contact with the bed. The multicorer design is simple; however, it has many points of failure given the working conditions and sediment characteristics. We found that cleaning and drying the instrument completely before each deployment minimized freezing of crucial parts and maximized coring success. The free-fall gravity corer was designed to be simple and robust to prevent problems working in these conditions. It could be deployed as a gravity corer simply by running the winch (McArtney MASH 4K) at full speed (~50 m/min). Additionally, in freefall mode, an 18.2 kg messenger could trigger the release of the 545 kg weight and core barrel package from a brailer to give it significantly higher downward velocity than a typical gravity corer tethered to a winch. The simple design allowed for relatively easy cleaning of all components prior to clean-access deployment and did not involve any hydraulic fluids that could potentially leak into this unique environment. Design, operation, successes, and potential improvements of the coring systems for future subglacial deployments will be discussed. Retrieval of sediment samples from Mercer Subglacial Lake will provide complementary data to water and particulate samples also retrieved, allowing the SALSA project to significantly advance our transdisciplinary understanding of these remote and untouched environments.

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Observation of the Subglacial Lake in the David Glacier area in Victoria Land

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The Antarctic Ice Sheet, which has a significant impact on current sea level changes and climate changes, is one of the international scientific issues. An aviation platform is a useful research approach that is used in many countries to minimize the disadvantages of accessibility throughout Antarctica. This study describes the research conducted using the helicopter-based IPR system (HiCARS2) which is developed by the Korea Polar Research Institute (KOPRI) and the University of Texas Institute for Geophysics (UTIG).
During the 2016/17 and 2018/19 Summer Seasons, KOPRI and UTIG conducted researches using HiCARS2 to find out the presence of unknown subglacial lakes and the detailed size of lakes (David 1, 2) in the David Glacier area in Victoria Land. In the first round of survey in the 2016/17 season, we looked for potential candidate lakes and conducted a second round of survey in the 2018/19 season to observe the detailed information of subglacial lakes on the David 2 area identified by Smith et al. (2009) and Blankenship et al. (2009).

We obtained the altitude at the air-snow interface of the David glacier and at the glacier-bedrock interface from the results. Glacier water flows and its route was identified from the glacier-bed reflection power and topographic information.
The Cryosat-2 data in 2010-2014 did not detect the elevation changes in from the D1 area but detected the elevation change slightly in the D2 area. In the first round of the survey, no flat and strong reflection that could infer the presence of lakes was found in the D1 area. However, in the second survey, we found a small valley with a width of about 3 km appears in the D2 area and high reflection intensity appears in the same area. The valley is topographically shaped to be easy to collect water and the higher reflection intensity of this area is interpreted because the dielectric constant of the water is larger than the bedrock.

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Taylor Valley Perennially Ice-Covered Lakes, past, present and future elevations, ice cover and implications for Connectivity

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Lakes in Taylor Valley in the McMurdo Dry Valleys are closed basin and acutely sensitive to changes in the local surface energy balance. When the balance is positive, lake levels rise, and when negative lake levels fall. We have a good record of historical lake level fluctuations from a number of sources: 1. Perched deltas paleo shorelines on valley walls above current levels, 2. Sediment cores from the current lakes, 3. Thermal signatures left in the subsurface from larger than present water bodies, 4. Salt signatures in the soils, 5. Chemical structure of the current lakes, 6. Historic observations from the earliest visits to Taylor Valley, and finally 7. Survey observations of lake surface elevation initiated by the New Zealand Antarctic program and maintained since the early 1990's by the U.S. National Science Foundation's McMurdo LTER. In this presentation I will discuss lake level history from these various lines of evidence, and discuss the history of connectivity from these fluctuations. Recently a new line of evidence from helicopter and ground-based EM observations have also shown how there is a previously unknown component to the water balance and connectivity of the Taylor Valley lakes in the subsurface. Inferred groundwater creates a connection between much of the eastern end of the valley and the coast, and the western end of the valley and the subglacial zone of Taylor Glacier. Fluctuating lake levels of the past and future, will also cause the hydraulic gradient in the subsurface to change – and even reverse – which is extremely important in shaping the biogeochemistry and presumably microbial diversity in the lakes. Another important response of these lakes to future energy balance changes will be a thinning of the perennial ice cover and transition to a seasonal ice cover.

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Session17: Paleoenviromental changes in Antarctica and Southern Oceans since the last Glacial Maximum

Coupled Iron and Carbon Cycling in the Southern Ocean and Impacts on Global Climate

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Understanding how climate change affects the environment is crucial to anticipating the impacts of future climate changes. Future climate predictions suggest that the Southern Ocean air-sea heat balance and carbon system account for most of the response of the ocean to global warming. The long-term trends of climatic cooling and increasing glacial cycle amplitude during the Plio–Pleistocene and Holocene glacial cycles involves changes across a broad spectrum of Earth system components involving the Antarctic Ice Sheet (AIS), iceberg, and dust and primary productivity. Higher dust transport from Patagonia to the Southern Ocean indicate periods of lower sea level, southward shifted winds and lower CO2 levels. The higher dust flux has been associated with Fe fertilization. The argument behind this is the "iron hypothesis" wherein the unused pool of macronutrients in the mixed layer of the Southern Ocean can be utilized for biological production when the aeolian dust deposition of Fe is increased. Paleoceanographic records from the Southern Ocean confirm this hypothesis, where the increased dust flux boosted the productivity and nutrient consumption and lowered atmospheric CO2 during the glacial times. To advance our knowledge of how the coupled Antarctic ice-ocean-atmosphere system evolved to the present state, this research focused on quantifying the role of dust variability over orbital timescales in the evolution of Plio-Pleistocene and Holocene glacial cycles and Fe fertilization and glacial CO2 drawdown.

Iron, an enzyme co-factor, is essential for marine photosynthetic organisms, assisting in cells' ability to grow, multiply, photosynthesize and fix nitrogen. Low Fe concentrations in the Southern Ocean result from both low Fe input and the insolubility of the metal. Iron is only sparingly soluble in oxygenated seawater and has a short residence time due to precipitation reactions and significant scavenging loss onto particle surfaces. Not all Fe delivered in the open ocean is bioavailable. For this reason, we investigated the relationships between Fe fluxes, bioavailable Fe distribution, primary productivity, and water-column redox throughout the Plio-Pleistocene and Holocene to advance the level of Fe characterization of the Southern Ocean. Our results suggest that Fe variability co-varied with orbital variability and the dust-climate feedbacks when set off by orbital forcing can drive the system in and out of extreme cold conditions such as glacial maxima.

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Biogeochemical modification of clay minerals in Antarctic region: Implications

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Biotic/abiotic redox reaction is frequently linked to the mineral alteration and elemental cycling. This reaction may bypass the thermodynamic and kinetic barriers that encounters the unexpected biogeochemical reactions and consequently, a new phase of mineral formation. Nonetheless, microbe-clay mineral interaction in cryoshpere is poorly understood. This study demonstrates the role of psychrophilic bacteria in clay mineral alteration in ice, sub-glacial sediments, and Antarctic soils. Implications will be discussed.

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Towards the complete mineralogical screening of Antarctic biogenic carbonates

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The assessment of the mineralogical composition of Antarctic carbonate skeletal parts is an ambitious undertaking, which started five years ago in the frame of the project "Geosmart" and is continuing within the project "Graceful", which are both funded by the Italian Program for Antarctic Research (PNRA). The aim of this research is to identify the mineralogical phases secreted by all the various marine carbonate-skeletonized benthic organisms inhabiting the Antarctic waters.
In addition, complimentary information is extracted in terms of geochemical composition (oxygen isotopes and stable carbon isotopes, trace and minor elements), and microstructure. Conceivably, the project should be seen as preparatory to applications, including a better understanding of the calcification mechanisms and responses to paleoclimatic changes including global warming and ocean acidification. Depending upon size and quantity of available material, the mineralogical composition is evaluated through standard x-ray powder diffraction or Raman spectroscopy. Although the screening is far from complete, the number of screened organisms is quite advanced and encompasses already most of those with recognizable paleoclimatic value, which occur in the pre-Modern record of Antarctica (such as raised beaches, tills, sedimentary cores and drillholes).
The modern baseline mineralogical composition of characteristic taxonomic groups will help in assessing their preservation status in fossil deposits. Their geochemical compositions are also influenced by their mineralogy and past environmental conditions, which can be better evaluated with multi-species assemblages. Raman spectra and XRD data show for instance characteristic peak shifts for varying content in Mg of calcite and can be used for paleothermometry and biomineralization studies. Today the Ross Sea provides the coldest marine environment on the planet and the isotopic and elemental compositions provide important extreme endmembers for temperature equations and other proxy calibrations.

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Deglacial history of the Anvers-Hugo Trough, western Antarctic Peninsula

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Changes in Antarctic sea ice cover, ice shelf stability and grounding line retreat, associated with atmospheric and/or oceanic warming, will have global and regional impacts including those on sea level, ocean circulation and marine ecosystems. Sedimentary sequences deposited since the Last Glacial Maximum (LGM; 25-19 ka BP) and during the subsequent deglaciation, provide an important archive of past ice sheet/shelf and sea-ice behaviour that provide analogues for current and future change. Here we present analysis of geological and geophysical data that record the last deglaciation of the Anvers-Hugo Trough (AHT), western Antarctic Peninsula shelf, collected during RRS James Clark Ross cruise JR284 in January 2014. The AHT is one of the best-surveyed Antarctic palaeo-ice stream troughs, which has enabled sediment coring and subsequent core interpretation within a well-known geomorphic context. Multi-proxy analysis and radiocarbon dating of sediment cores, as well as quantitative diatom species abundance and assemblage analysis, provide data sets that can be used to: (i) Constrain the timing of ice sheet retreat in AHT, (ii) reconstruct the palaeoceanographic setting of the AHT during and immediately after deglaciation and (iii) investigate the drivers of ice sheet retreat and the onset of post-glacial productivity by comparing our records of productivity and estimates of SST from diatoms with published records of atmospheric, oceanic and sea-level forcing. Radiocarbon ages obtained for this and previous studies, indicate that grounding line retreat was initiated prior to 16.4 cal kyr BP, with grounding line retreat across the outer and mid-shelf complete by 13.7 cal kyr BP. Retreat of the ice stream grounding line and the demise of an ice canopy, is followed by the onset of seasonally open marine conditions. This is indicated by the increase in absolute diatom abundance and in the abundance of diatom species associated with seasonal sea ice formation, spring sea ice melt and open water summer to autumn conditions. Diatom abundance and assemblage data indicate that a period of low biological productivity followed this initial onset of seasonally open marine conditions, associated with a persistent ice canopy. Enhanced productivity was initiated at 11.5 cal kyr BP, forming ponded laminated diatomaceous ooze deposits (>100 cm) within bathymetric depressions. Neighbouring cores recovered from shallower and more exposed bathymetric settings also document a peak in biological productivity at this time; however, only a thin (~10 cm) diatomaceous unit is observed. This suggests that environmental conditions favouring enhanced biological productivity between 11.8 and 9.5 cal kyr BP were widespread, whilst the seafloor topography played an important role in focussing and preserving diatomaceous ooze deposits. Enhanced productivity over this period was associated with a seasonal cycle of sea ice formation over the austral winter, sea ice melt in the spring and open-water summer and autumn conditions. Retreat of grounded ice and ice shelves within inner-shelf bays, as well as ice sheet thinning over this period, may have provided additional meltwater and nutrients to the Antarctic Peninsula shelf, promoting enhanced productivity.

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Holocene Glacial Fluctuations across the Antarctic Peninsula

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Little is known about the behavior of the Antarctic Ice Sheets and glaciers during the late Holocene. Proxy data suggests the presence of Neoglacial advances but few moraines or glacial features have been dated during this time period. Here we provide new evidence for Holocene glacial fluctuations from three locations along the northern Antarctic Peninsula. An Esker and Ground moraine from a small tidewater glacier cross cut a series of raised beaches at Tay's Head of Joinville Island along the northwestern Weddell Sea. Ages from the raised beaches constrain the advance to have occurred within the last 3095+/-195 cal BP but likely within the last 2240+/-155 cal BP The presence of rounded cobbles within the ground moraine and its placement between the higher raised beach and open water suggest the glacier retreated landward of its pre-20th century location before prograding past its current position and subsequently retreating. Another small moraine on Potter Peninsula, King George Island contains a seaweed trash layer overlying a shell-bearing sand. Both of these are overridden by glacial till. The seaweed and shells date the advance to having occurred after 7450 cal yr BP. A third site at Spark Point, Greenwich Island exposes a shell-bearing intertidal deposit that dates a glacier advance to have occurred in the last 290 cal yr BP. We discuss these unpublished ages within the wider context of a small number of other constraints on Holocene advances. The data reveal a potentially complex Holocene history of glacier fluctuations in the northern Antarctic Peninsula, which require further efforts to disentangle. These mid-Holocene readvances provide a possible mechanism for driving recently documented changes in Holocene relative sea levels across the Antarctic Peninsula and suggest the Antarctic Ice Sheets may have been more responsive to past climate changes that previously thought. New glacial-isostatic and glaciological models should include these neoglacial advances.

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Subglacial Carbon Pathways Associated with Whillans and Mercer ice streams: A SALSA and WISSARD Sedimentary Perspective

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High rates of grounding line retreat and ice mass loss from the West Antarctic Ice Sheet (WAIS) since the Last Glacial Maximum have been attributed to fast-flowing ice streams along the Siple Coast. Knowledge of specific style and timing of retreat is limited, in part, due to the poorly constrained chronologies and far-field, marine-based sedimentary records. Two subglacial access drilling efforts in the last decade, Whillans Ice Stream Subglacial Access Research Drilling (WISSARD, 2013 & 2015) and Subglacial Antarctic Lakes Scientific Access (SALSA, 2018-2019), have recovered sediment cores from subglacial archives beneath Whillans and Mercer ice streams. From these efforts, we can use subglacial lake and grounding zone sediments for reconstructions of past WAIS variability.
Furthermore, knowledge of the extent and timing of past WAIS variability allows us to elucidate how relict organic matter deposited during marine incursions influences carbon cycling in subglacial environments. Here we present biogeochemical evidence constrained by acid insoluble organic matter Ramped PyrOx 14C ages illustrating the role of organic carbon input to these sediments during the Holocene. These unique sedimentary records provide new information on retreat history along the Siple Coast, broadening our understanding of processes that introduce labile (thermochemically reactive) carbon to subglacial environments.

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Holocene drivers of biogenic bloom events linked to extratropical teleconnections, offshore Adélie Land, East Antarctica

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Understanding the imprint of climate oscillations on normal climate variability in Antarctica is difficult due to the sparse and temporally limited satellite and observational data. It is therefore challenging to characterize long term centennial and decadal variability, particularly along the coastal margins where complex oceanographic, atmospheric, and biologic interactions take place. Crucial components of the climate system along the coastal margins may be capable of change at centennial and decadal timescales, including sea ice extent, primary productivity, ocean circulation, and bottom water formation. Here, we present a new Holocene climate record from Integrated Ocean Drilling Program (IODP) sediment core U1357B in the Adélie Basin, East Antarctica. The sediment core consists of contrasting light and dark centimetre scale laminations through the entire 170 m of core, with light laminations representing mass biogenic bloom events. Using X-Ray Computed Tomography, and supported by XRF data, diatom analysis, and other physical properties, we developed a record of near annual biogenic bloom events and link these bloom events to changing environmental conditions throughout the Holocene. Baseline shifts in laminae frequency correspond with changes in El Niño-Southern Oscillation (ENSO) frequency and intensity in the Holocene as noted in globally distributed paleoclimate records. ENSO's impact on Adélie Land has implications for the Southern Annular Mode (SAM) which regulates the impact of ENSO on Antarctica and is not well defined in the paleoclimate record.

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Ocean temperature control on ice shelf and glacier extent around the Antarctic Peninsula throughout the Holocene

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The Antarctic Peninsula is one of the most affected regions on Earth by the global warming. Both surface atmosphere and subsurface ocean temperatures have rapidly increased over the last decades and contributed to massive regional ice shelf and glacier regressions. However, we still need to further understand the relationship between changes in temperatures and ice cap, especially around the North of the Peninsula where the glaciers have the potential to raise sea level by nearly 70m. To this aim, we provide a new subsurface ocean temperature (SOT) (50-400m) record in the northern Antarctic Peninsula spanning the last 9,000 years before present (BP). We applied the TEX86L (TetraEther Index of tetraethers with 86 carbons) proxy for low temperatures to the relatively well-dated marine core Jumbo Piston Core (JPC) 33, retrieved in the southern Bransfield Strait. Our new Holocene SOT record reveals a strong +3ºC warming episode between 8.3 and 6.5 kyrs BP, before a cooling period preceding a second +2ºC warming phase during the last 4.0 kyrs BP. These two warming intervals are synchronous with pronounced regional ice shelf and glaciers retreat. Similar connections between increasing SOT and ice cap recession have also been reported along the Western and Eastern Antarctic Peninsula, thus confirming the predominant role of the SOT, mainly tied to the enhanced supply of relatively warm subsurface deep waters onto the ice shelf, on the ice cap extent over the last millennia.

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Insights on the duration of late Pleistocene ice expansion from in-situ 14C dating of bedrock surfaces

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The duration of ice advance during Last Glacial Maximum (LGM) in Antarctica provides insight into its overall sensitivity to environmental thresholds, the response time of the ice sheet to climate and sea level perturbations, and is an essential component in understanding present day Glacio-Isostatic response of the crust to past ice sheet geometries. While measuring the timing of ice retreat has become relatively routine through the advent of Be-10 exposure dating, determining the onset of glaciation remains difficult due to the challenges of obtaining pre-glacial sediments.

The measurement of in-situ C-14 in bedrock surfaces provides a low-resolution temporal approach that enables an understanding of whether LGM ice cover was brief or extended back beyond MIS3. Here, we present new observations from Princess Elizabeth Land in East Antarctica that demonstrates differing responses of the inland and coastal portions of the ice sheet. Inland at Mt Brown, C-14 inventories in bedrock are consistent with a 'long duration' LGM, with the ice sheet remaining at the maximum limit for much of MIS 2 & 3 before thinning in the early Holocene. In contrast, ice advance in coastal regions at Rauer Group was brief, and the areal limit of the ice sheet was similar to or smaller than today during MIS 3.

This new evidence contributes to our understanding of the 'relative sea level paradox' recorded sediments around Prydz Bay, which indicate both an increased ice load, but aerially restricted ice extent during MIS 3. However, it in turn points to an intriguing pattern of environmental forcing (e.g. warm ocean with high snow accumulation) for the ice sheet that is worthy of further investigation through ice core and marine sediment proxies and modelling.

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A HIGH RESOLUTION DEGLACIATION RECORD OF ADÉLIE LAND (EAST ANTARTIC MARGING; IODP SITE U1357A).

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Recent studies demonstrate the dominant role of ocean forcing in driving Antarctica last deglaciation. The East Antarctic Ice Sheet (EAIS) has long been viewed as very stable, but recent works doubt on this view and poorly it is known about how ocean forcing affected this region. In this sense, the role of Antarctica during the last deglaciation and its contribution to the melt water pulses and major climate variations during this period remains poorly known. This poor knowledge is related with the complex shelf sedimentation, low sedimentation rates, large reservoir age and dating problems among others. In order to reconstruct in detail the last deglaciation paleoenviromental changes in EAIS domain we selected marine site U1357A and applied a wide range of geochemical, paleontological and sedimentological techniques.

The site U1357A recovered a unique last deglaciation sequence (between 176 to 185 mbsf), with several unique features as periodic detrital layers between biogenic lamina at sub-annual resolution. Biogenic laminated sediments consist predominantly of diatom and radiolarian remains and cyclic coarse detrital layers (silts and ice-rifted debris). This sequence is characterized by the presence of E. antarctica spores with values >15%. This diatom indicates strong water column stratification. High values in D/T and ice sea proxy species (e.g. Fragilariopsis curta + F. cylindrus) indicate abrupt variations in sea-ice during this interval and shows a good correlation with bottom redox proxies (U/Th), pointing to lower oxygen availability when sea-ice is present. Comparison between CT-Scan images and geochemical data demonstrate that the intervals with high Ba/Al and Si/Al are associated to poor detrital levels, allowing to use these ratios as detrital/paleoproductivity proxies. During the deglaciation highest Holocene relative high detrital input occurred. CT-Scan images also corroborate an erosional character for these silty layers. Detrital proxies (e.g., Zr content) are anticorrelate respect to bottom redox conditions proxies (U/Th), pointing to well oxygenated deep waters as generator for silty layers. All these preliminary evidences allow us to recognize an unprecedented high resolution ice fjord-like sequence in the studied region with strong water column stratification and pulsational detrital input acting as a main forcing for environmental variations. Ongoing radiocarbon analysis, performed in the bulk fraction and also in compound-specific, will allow us to recognize timing, cylces and if major variations occurred in the reservoir age during the deglaciation. The ratio of the concentrations of highly branched isoprenoid (HBI) diene/triene (D/T), a diatom specific biomarker, also has been used as a proxy for relative inputs of sea-ice algae and open water phytoplankton that gives indication on past sea-ice cover. Organic proxies indicate "warm" conditions and no sea ice. Redox proxies indicate well oxygenate sea bottom conditions.

Described organic and inorganic geochemical proxies variations can be explain by environmental

conditions dominate by water column stratification and detrital inputs from aprox. 11.7 to 10.5 ky cal BP. Deglaciation is punctuated by abrupt changes in certain proxies probably linked with major changes when melt water influence decreased.

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Have we been right about the timing of the last deglacial in Antarctica?

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Several key works and hundreds of citations have built upon Antarctic margin sediment deglacial dates measured in acid-insoluble organic matter. During the same time, other potentially more accurate dating methods for Antarctic margin sediments have become available. Here we compare these methods in prominent Antarctic margin deglacial lithotypes to establish the benefit and practicality of employing them on a more widespread basis. The methods we put forward for comparison are radiocarbon dating of both thermochemically-separated (Ramped PyrOx 14C, or RP14C) and chemically-extracted sedimentary organic matter (compound-specific diatom 14C, or CSD14C). These preparatory methods aim to separate syndepositionally-fixed organic carbon from pre-aged detrital organic carbon, both of which are incorporated in bulk acid-insoluble organic matter (AIOM) dates. Without separation of these two pools of organic carbon, 14C ages can be older than the true depositional age of the sediments – yet much of our literature is based on this approach. We employ each 14C dating method (RP14C, CSD14C, and AIOM) as well as carbonate microfossil 14C ages, where available, in sediments recovered from East Antarctic and western Antarctic Peninsula continental margins. At each location, we target a laminated diatom ooze and silt lithotype overlying diamict, and we select sample depths that allow for a direct comparison of new RP and CSD14C-derived ages with existing bulk AIOM and/or carbonate-based 14C ages. Our results indicate that the majority of RP and CSD14C-derived ages are younger than the bulk AIOM 14C ages, and where available, are similar to carbonate 14C ages, supporting an improved accuracy in dating this lithotype. Additionally, except for one site, the RP-derived ages are consistently younger than the CSD14C ages, supporting RP14C as the most accurate 14C method for this lithotype. We posit that changes in the depositional environment drive the accuracy of each of our methods, e.g., higher autochthonous sedimentation results in more accurate AIOM ages, minimizing the difference between 14C dating methods. In this comprehensive comparison study of RP and CSD14C dating, our new data suggest a more synchronous regional ice-sheet retreat than previously hypothesized from the Mac. Robertson Land continental shelf, East Antarctica. Our results suggest that in these deglacial sediments, RP-based 14C ages are the best approach in the absence of biogenic carbonate, and we hypothesize that a reanalysis of additional deglacial sediments using RP-based and, in some cases, CSD14C-based ages will improve the accuracy of regional deglacial timings.

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Ocean Heat Transport Variability off Wilkes Land, East Antarctica

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One of the greatest risks from global climate change is sea-level rise and the largest uncertainty in future global sea level rise prediction is the contribution from Antarctica. The key to a more precise estimate is better understanding of the role oceans play beneath the fringing ice shelves, especially basal melting. However, due to the inclement weather and the obstruction from the sea ice cover, observing the coastal physical oceanic processes and the ice shelf cavity evolution as it melts is tough and very costly. Therefore, one of the most effective ways to explore the secret lives of ice shelves is via design of suitable numerical models. Observational studies have confirmed that in addition to the well-known ice shelves in the Amundsen and Bellingshausen Seas of West Antarctica, some of those in East Antarctica are also rapidly thinning, especially the Totten Glacier and nearby ice shelves. Melting of these ice shelves is mostly driven by warm and saline modified circumpolar deep water, but the mechanism delivering this water to the ice shelf cavity is not well studied yet. In our research, we use the Regional Oceanic Modelling System (ROMS) to simulate ice-ocean interaction around Wilkes Land, Antarctica, focusing on Totten Ice Shelf (TIS) and Moscow University Ice Shelf (MUIS). The model has horizontal resolution varying from 1.4 km to 1.9 km, and is both tidal-resolving and eddy-resolving. During the simulation period (year of 1992), the two ice shelves fed from Totten Glacier had a total mass loss of 122.38 Gt, and the melt rate shows strong seasonal variability. To understand how much heat being transported onto the continental shelf and into the ice shelf cavity, we extracted two zonal profiles along the continental shelf break and the ice shelf front, respectively. Finally, we use decomposition methods to quantify the relative roles of eddies and tides in transporting heat to the ice shelf cavities, thus taking steps towards explaining the mechanisms that deliver heat to these susceptible regions of Antarctica.

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Ocean Processes South of the Drygalski Ice Tongue, Western Ross Sea

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Here we describe the first ever year-round oceanographic mooring timeseries from a location just south of the Drygalski Ice Tongue that is subject to katabatic winds and also northward flowing Victoria Land Coastal Current. An oceanographic mooring was deployed in Geikie Inlet (not to be confused with an equivalent named place in the Arctic) through all of 2017. This was coupled with several equivalent contemporaneous moorings to the north of the Drygalski. Temperature and salinity are consistent north and south of the ice tongue albeit with a of lag of ~12 days in both Temperature and Salinity (but at different times). We consider if there is a consistent polynya to the south of the DIT and are there implications for the TNB Polynya? Is the oceanic region quiescent and/or can we see Ross Ice Shelf outflow signature. Finally, what are the implications for our understanding of the local/regional ice shelf cavity circulation?

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Sea ice extent and variability monitoring and wind speed retrieval along polar Marginal Ice Zones using SCATSAT-1 scatterometer and SAR data

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Dramatic decline of Antarctic Ocean sea ice area, extent and thickness has reinvigorated research on the role of sea ice in climate variability and change. Sea ice is one of the most important, dynamic and ever changing component of ocean ecosystems and a key indicator of climate change. Along with other elements of polar ecosystems, sea ice is a part of the global climate system and plays a crucial role in its regulation. The area covered by sea ice grows in the winter and shrinks in the warmer months. This variability in sea ice is closely linked to the marine biology and marine ecosystem. The presence or absence, increase or decline in sea ice also plays an important role in the dynamics of energy balance, since ice reflects more than 80 percent of the solar radiation back in space. While, on the other hand ocean surface absorbs 90 percent of the radiation. But the monitoring of the annual variability of sea ice is not easy, at least through traditional methods. Remote Sensing provides a viable and dependant alternative to this problem. The following study uses remote sensing datasets for sea ice variability monitoring and wind velocity vector generation in the Marginal Ice Zones (MIZ) of Antarctica. SCATSAT-1 is India's satellite carrying a Ku-band Scatterometer on board. It provides daily images of the complete Antarctic continent both in VV and HH polarizations at 2.25 km spatial resolution. Backscatter thresholding for sea-ice extent mapping was performed from October 2016 till March 2019 to monitor sea ice variations. Although NSIDC provides sea-ice extent daily maps for Arctic and Antarctica, but this is a first attempt to generate such maps using Scatterometer datasets. The maximum sea-ice extent of 18.154 Mkm2 over the study period was estimated on 38/09/2018, while the minimum sea-ice extent of 2.01 Mkm2 was estimated on 03/03/2017. The results match the estimates provided by NSIDC for sea-ice area extent. Thus scatterometer backscatter thresholding provides a feasible alternative to the passive radiometer sea-ice extent monitoring methodology applied commonly. Marginal ice zone (MIZ) is the area between the pack ice and the ice edge in the polar waters. It consists of ice that is broken up by wave activity and dispersed by wind and currents. For wind-speed retrieval, empirical model functions relating the Normalised Radar Cross Section of the ocean surface to the local near-surface wind speed (V), wind direction versus antenna look direction (Φ), and incidence angle (θ) have been developed. These models are mainly developed to identify the relationship of wind speed at 10 m to Normalized Radar Cross Section (NRCS) for open oceans with a neutrally stable atmosphere. Retrieving wind speeds along the marginal ice zones is challenging due to the effect of surface drag. Also, the MIZ of Antarctic coast does not always have clearly visible surface wind streaks, as is the case of normal costal or sea surface. The surface streaks visible of SAR data can also be due to sea-ice or floes found near the MIZ making it very hard to predict wind direction. An attempt has been made to retrieve wind velocities especially along Marginal Ice Zones of Antarctica using RISAT 1 and Sentinel 1 A/B SAR data in VV polarization. The results of 26 March 2014 RISAT 1 MRS image shows that wind speed from SAR data using CMOD5, CMOD_IFR2 and polar WRF model came in range of 19.40 to 20.27 m/s, 9.26-14.59 m/s and 15.43-22.21 m/s respectively. Wind direction from polar WRF model is in range of 313-326 w.r.t North direction. The results of wind direction are fairly consistent with those provided by Antarctica Mesoscale Prediction System (AMPS) provided by NSIDC.

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KOMPSAT5 Satellite Sea-Ice Image High-Frequency Multiplicative Noise Effects Analysis Based on Joint Complex Time-Frequency Domain Method

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Allowing the acquisition of high-resolution images of the surface of the earth under all-weather and all-time conditions, synthetic aperture radar (SAR) satellite represents a very powerful observation tool for lands and oceans monitoring. However, precise texture analysis and accurate interpretation of the image information contained within the backscattered data of the SAR is extremely difficult. These difficulties are due to the inherent characteristics of the electromagnetic waves scattering phenomenon that can be regarded as a high-frequency multiplicative noise (HMN) adverse presence within the SAR 2-D image, which makes the coherent image processing and texture analysis with challenges. This is mainly caused by the difference in the distance of the pulses travel back from point scatterers due to the surface roughness, antenna-platform displacements or etc., and makes the received pulses to have random phase shift on receive and affects the coherent processed image with a random pixel-to-pixel abrupt intensity changes or slow variation anomalies, which are known as HMN.

So far, various SAR satellites are operating with different system parameters, which are not only differing in the size and the orbits but also varies in the mode and the image resolution. The KOMPSAT5 satellite is one of the SAR sensors which is designed to provide 2-D gray scale images of the earth surface for the purpose of geographic information applications and environmental disasters monitoring. Considering the application and the operation of KOMPSAT5, the above HMN presence challenge is also true and has adverse effects in the SAR 2-D image reconstruction and presentation. Due to the fact that SAR sea-ice images are helpful for polar monitoring, climate change studies, safe navigation and other probable operations and researches, this paper will analyze the HMN adverse effects presence in the KOMPSAT5 imagery with the help of joint complex time-frequency domain (TFD) technique. The advantage of the proposed TFD method is to provide a power spectral density (PSD) function modeling of HMN level in the SAR sea-ice image, specifically one which has been formed by KOMPSAT5. The simulation results are not only helpful for the sensor designing and development techniques but also applicable in the SAR sea-ice texture analysis. The proposed TFD method is based on using statistical properties of the texture on the basis of time and frequency decomposition presentation.

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Monitoring iceberg A68 calved from the Larsen C Ice Shelf using satellite remote sensing

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Iceberg A68 calved from the Larsen C Ice Shelf, Antarctic Peninsula, in July 2017. In this study, we analyze the initial evolution of iceberg A68 in terms of changes in its area, drift speed, rotation, and freeboard using Sentinel-1 synthetic aperture radar (SAR) images and CryoSat-2 SAR/Interferometric Radar Altimeter observations. The study period extends from July 2017 to end of 2018. The area of the iceberg sharply decreased in mid-August 2017 and mid-May 2018 via large calving. The area of A68 decreased only 2% over 1.5 years. A68 was relatively stationary until mid-July 2018, while it was surrounded by the Larsen C Ice Shelf front and a high concentration of sea ice, and when its movement was interrupted by the shallow seabed. The iceberg passed through the front of the Larsen C Ice Shelf after July 2018, showing a higher drift speed and greater rotation. The freeboard of A68 decreased at an average rate of –0.80±0.29 m/a during February–November 2018, which could have been due to basal melting. The freeboard measured from CryoSat-2 could represent the returned signal from the snow surface on the iceberg. Based on this, the average rate of freeboard change was estimated at –1.62±0.30 m/a during the study period considering an average rate of snow accumulation of 0.82±0.06 m/a predicted by reanalysis data from the Modern-Era Retrospective analysis for Research and Applications, Version 2.

A310

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Estimation of ice shelf thinning derived from surface depression of an ice rumple

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Ice rumples are locally-grounded features of flowing ice shelves, elevated tens of meters above the surrounding surface. These features may significantly impact the dynamics of ice-shelf grounding lines, which are strongly related to shelf stability. However, the observation of such surface feature was hardly carried out due to its small size. The present study was designed to observe and better understand the transient nature of the ice rumple surface elevation. We used DLR's TanDEM-X and TerraSAR-X bi-static SAR data to construct high-resolution DEMs of the Thwaites ice shelf in West Antarctica from 2011 to 2013. During the period 2011-2013, the deformation maps showed the presence of an ice rumple and its recent fading. The ice rumple may have appeared sometime between the observations of a grounding line of the Thwaites glacier using Double-Differential Interferometric SAR (DDInSAR) in 1996 and 2011. The observed degradation of the ice rumple during 2011–2013 may be related to a loss of contact with the underlying bathymetry caused by the thinning of the ice shelf. We used a viscoelastic deformation model with a finite spherical pressure source to interpret the surface changes in terms of pressure changes at the bottom of the ice shelf. Global optimization allowed us to fit the model to the observed deformation map, producing reasonable estimates of the ice thickness at the center of the pressure source. Then, we calculated the thickness change using the estimated thicknesses from the viscoelastic deformation model. The thinning rate was much higher than that of previously reported levels, suggesting strong melting at a local pinning point. We conclude that combining the use of multiple high-resolution DEMs and the simple viscoelastic deformation model is feasible for observing and understanding the transient nature of small ice rumples, with implications for monitoring ice shelf stability.

A438

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Ocean-driven thinning of Totten and Shackleton Ice Shelves, the two primary outlets of the Aurora Subglacial Basin in East Antarctica

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The Aurora Subglacial Basin (ASB) in East Antarctica contains at least 3.5 meters of eustatic sea level potential in ice grounded below sea level primarily draining through the Totten and Denman Glaciers located along the Sabrina and Knox Coasts, respectively. The ice surface elevation in the Totten and Denman grounding zones has been lowering steadily since the beginning of the satellite altimetry record and their grounding lines are retreating. The ice within the ASB is believed to have collapsed and advanced multiple times since the onset of large scale glaciation so it is imperative to understand what is driving the contemporary changes.

Basal melting of the Totten Glacier Ice Shelf (TGIS) was recently shown to be driven by warm, modified Circumpolar Deep Water (mCDW) that enters the ice shelf cavity through a system of seafloor troughs connecting to a reservoir of mCDW that has been observed on the nearby continental shelf since 1996. Totten Glacier is also susceptible to seasonal surface melting owing to its relatively northern latitude. Using airborne ice penetrating radar data we show that the ocean actively melts large channels into the ice shelf base that grow to over two kilometers wide and 350 meters deep with steep walls and flat terraces characteristic of rapid melt. We also apply airborne surface radar analyses to show that the near surface of the ice shelf (within the firn layers) undergoes widespread melting in warm years as indicated by the closest available automatic weather stations. The natural vulnerability of the TGIS to surface and basal melting is concerning given recent numerical modeling results indicating that ocean melting and surface melt-induced hydrofracture and ice cliff failure could cause substantial retreat into the ASB.

Denman Glacier drains through the Shackleton Ice Shelf (SIS), the seventh largest and the most northern ice shelf in Antarctica outside the Antarctica Peninsula. Denman's rapid coastal thinning and the high rate of basal melt rate observed on the SIS, combined with our knowledge of mCDW access to the TGIS, suggest that ocean-driven thinning could be responsible for changes in the ASB's western outlet, as well. However, the sub-ice shelf bathymetry and nearby ocean state of the SIS have not been known well enough to confirm that hypothesis. Here we present a new sub-ice shelf bathymetry compilation for the eastern SIS derived from an airborne gravity inversion using a geological model constrained by seafloor depth estimates. Depth constraints were estimated from airborne-deployed bathythermograph sensors and depth to basement solutions from airborne magnetics data. The new bathymetry reveals at least one seafloor trough deep enough to allow mCDW observed by Autonomous Pinniped Bathythermographs (tagged seals) near this location to reach the grounding line. Finally, we use ice core data acquired nearby to confirm that atmospheric temperatures have not been high enough since at least 1931 to explain the thinning observed in the Denman grounding zone. These results confirm that both outlets of the ASB, via Totten and Denman

Glaciers, are vulnerable to ocean-driven retreat also known to be responsible for rapid thinning of several glaciers in West Antarctica.

A454

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Mass Balance Assessment of the Lambert Glacier-Amery Ice Shelf System , East Antarctica

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The Lambert Glacier-Amery Ice Shelf System (LG-AIS) is the largest glacial systems in East Antarctica. The accurate estimation of its mass balance state is imperative to calculate its contribution to global sea level rise. Here, we present a comprehensive investigation of the LG-AIS. We measured the ice velocity and mapped a new grounding line of the Amery Ice Shelf (AIS) with Sentinel-1A and 1B SAR data acquired in 2016. Combined with the ice thickness data from radio echo sounding (RES) measurements and the surface mass balance data from the new Regional Atmospheric Climate Model, version 2.3p2, the mass budget of the AIS drainage basin was precisely estimated. We found several notable differences between our grounding line product and former results, which is important for expanding our knowledge of AIS grounding zone dynamics and the interactions between the ice shelf and ocean. Our measurements show that the LG-AIS is gaining mass, with a positive mass budget of 5.0 ± 9.1 Gt/yr in 2016. After comparing our results with those of previous studies, we report that, although short-term surface mass balance fluctuations dramatically affect the AIS basin mass budget, a long-term positive mass balance trend from the 2000s to 2016 has been confirmed.

A026

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Possible influence of the Antarctic Oscillation on haze pollution in North China

Ziyin Zhang [1†]

In this study, the possible influence of the Antarctic Oscillation (AAO) on winter haze pollution (indicated by atmospheric visibility after rain, fog, dust, snowstorms, etc., are removed) in North China (NC) was investigated. The results show that the mean winter visibility (DJF-VIS) throughout most of eastern China is negatively correlated with the preceding AAO (August-September-October, ASO-AAO), especially in NC. The interannual correlation coefficient between DJF-VIS in NC and the ASO-AAO is -0.52, which is significant at the 99% level. The negative correlation suggests that an enhancing (weakening) ASO-AAO could be conducive to increases (decreases) of haze pollution in NC in boreal winter. The responses of local and regional meteorological conditions to the ASO-AAO support the relationship between the ASO-AAO and winter air pollution in NC. A preliminary mechanism analysis shows that a positive ASO-AAO may induce a sea surface temperature (SST) warming tendency in the Northwestern Southern Indian Ocean (NSIO). This warming then causes a wave train-like pattern in the upper troposphere along the jet stream and an anomalous zonal cell that weakens the regional Hadley Circulation from the Maritime continents to East Asia. All of these factors are favourable to the formation of anomalous southerly and haze pollution in NC.

A035

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Does the combined effect of the Indian summer monsoon and Indian Ocean Dipole modulate the September Antarctic sea ice?

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Since the beginning of the satellite era, it has been observed that the Antarctic sea ice exhibits a positive trend in sea ice concentration and asymmetry in the regional distribution of sea ice. Currently, it shows an increasing trend in the Weddell Sea, Southern Pacific Ocean, and the Ross Sea while a decreasing trend in the southern Indian Ocean, Amundsen Sea, and the Bellingshausen Sea. Many studies linked the asymmetry in sea ice distribution with the Atlantic and Pacific Sea Surface Temperature (SST) while a very few related it to the Indian Ocean SST patterns. Concurrently few studies statistically linked the Antarctic sea ice with Indian summer monsoon (ISM), but hardly any of the studies exhibited a physical mechanism through which the large-scale atmospheric circulation associated with the Indian summer monsoon (ISM) influence the Antarctic climate variability. The objective of the present study is to investigate the interaction between ISM - Indian Ocean Dipole (IOD)- Antarctic sea ice, elucidate the physical mechanism through which ISM and IOD modulate the Antarctic sea ice and their feedbacks, by using observational/reanalysis/satellite data and climate model simulations. IOD, a coupled ocean-atmospheric phenomenon which occurs in the tropical Indian ocean and has a linear relationship with ISM. The preliminary results from the analysis of NCEP/NCAR reanalysis and Hadley Centre Sea ice and Sea Surface Temperature data showed that the September sea ice concentration anomaly during 1994, a year with strong positive Indian Ocean Dipole (IOD) and strong ISM, exhibited an opposite feature in sea ice distribution when compared with the current trend. The spatial regression patterns of boreal summer the Amundsen Sea mean sea level pressure on Indian Ocean SST anomalies illustrated a positive IOD like feature in the Indian Ocean, that point towards an IOD-Antarctic climate relationship. The study will be extended to analog cases apart from 1994 and will investigate the impact of different flavors of IOD on Antarctic sea ice. Further research using climate model simulations will be done to fully understand how the synergism between ISM and IOD influence the Antarctic sea ice. The study establishes a tropical-polar teleconnection that links the ISM-IOD and Antarctic sea ice during boreal summer.

A039

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Recent Antarctic Peninsula cooling derived by southern stratospheric polar vortex weakening

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In contrast to the overall rapid warming over the Antarctic Peninsula (AP) for the past 50 years, there has been a cooling trend since 1999. The temperature observed at the King Sejong (KSJ) station in the King George Island off the AP since 1989 also shows the cooling trend. The cooling trend found in the AP is reported to be caused by a shift in cyclonic center to the Drake Passage and the Weddell Sea, that brings about cold air from the east to the AP region.
In this study, we propose that the strong southern stratospheric polar vortex (SSPV) weakening is responsible for the AP cooling. Since 2000, the strong SSPV weakening events, which is defined as higher polar cap height (PCH) anomaly at the middle layer of stratosphere, have occurred more frequently during the late winter and early spring (August-October), especially in October. When there is strong SSPV weakening event, surface air temperature (SAT) in the AP appears to be colder than normal from October to January associated with the downward propagation of higher height anomaly to surface, whereas warmer in the rest of Antarctica, as a reminiscent of negative phase of Southern Annular Mode (SAM). This is supported by daily SAT records measured at the KSJ station, where the cold anomaly persists for about three months after the onset of the strong SSPV weakening events. The daily PCH anomalies also have increasing trend toward present, consistent with the more frequent occurrence of the strong SSPV weakening events since 2000. The more frequent weaker SSPV events since 2000 seem to play an important role in the AP cooling during spring and early summer.

A105

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Climate variability in the West Antarctic sector and potential of seasonal predictability of the tropica Pacific and Atlantic zone

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Assessment of the climate change in the West Antarctic sector and seasonal predictability potential in the Antarctic Peninsula (AP) region as viewed against El-Nino-Southern Oscillation (ENSO) variability is the main purpose of the research. Regional climate variability has been assessed on the centennial time scale showing two episodes of warming in 20-21st century, and showing growing influence of the El-Nino-Southern Oscillation, emphasizing that predominantly natural factors are fundamental in shaping the current climate.

Two periods of warming and mid-century period with relative cooling are juxtaposed showing that different climate epochs imply different types of atmospheric teleconnections.

An increase in the near-surface air temperature (SAT) during the second phase of warming has been peaked at the western coast of AP in 1986-2005, during the warm ENSO phase. El Niño, was found to be responsible for the regional climate variability and individual climate extremes It is shown how the large-scale atmospheric circulation in the West Antarctic sector varies depending on the ENSO episode; the ENSO signal is traced to the lower stratosphere. Detailed climatology is done for the regional stations showing peculiarities in the behavior in the meteorological parameters: smoothing daily and seasonal SAT ranges, growing precipitation, intensification of surface winds. Atmospheric teleconnections as well as transitions between scales, from synoptic to regional are studied including local winds and currents, sea-ice.

In the atmospheric circulation, the recent warming period is characterized by intensified westerlies and prevailing cyclogenesis in the West Antarctic especially in the Bellingshausen Sea. The influence of ENSO on regional circulation and weather at the Antarctic Peninsula region is displayed in the best way on time scales from seasonal to half-an-year after its mature phase in the behavior of the large-scale synoptic systems such as stable (like-blocking) anticyclones and circumpolar trough governing the intensity of cyclones.

Latest decade shows a new shift in a regional climate, with some cooling on the Antarctic Peninsula stations, followed by some change in the atmospheric circulation: reverse in the sign in regional indexes and growing residence time of atmospheric circulation types, that depends on the duration of the ENSO phase.

Potential of seasonal predictability of the equatorial Pacific and Atlantic zone is shown. A high synchronous and asynchronous correlations are found between SAT anomalies in the Antarctic Peninsula and ENSO indexes; with the best correlation reached through the East Pacific index. The South Atlantic index can be used to overcome the seasonal barrier of the seasonal predictability in the austral spring. Regression and alternative forecast schemes for the seasonal SAT for the West Antarctic stations are calculated, with the best skill for the cold half of the year. The need for further research is indicated, as we have a limited set of El Niño episodes.

A124

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Relationship between total ozone and regional meteorology around the Weddell Sea

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We examined how the total ozone column (TOC) relates to ambient meteorological factors around the Weddell Sea. We analyzed ground-based and satellite TOC measurements compared to air temperature and potential vorticity from reanalysis data. Basically, recent recovery pattern of TOC was found in spite of large annual variation. TOC pattern around the Weddell Sea shows the large meridional difference particularly during the austral springtime, showing the spatially different influence of polar vortex in this region. The TOC pattern around the Weddell Sea has high correlations with air temperature but the signal is vertically different: high positive correlations in the lower stratosphere, but the high negative correlations in the upper stratosphere. This contrast can be explained by the enhanced lower stratospheric ozone depletion related to the cold temperature (i.e., polar stratospheric clouds are well developed) and the relatively stronger ozone production rate in the cold temperature of upper stratosphere. The TOC also has another contrast of correlations with the potential vorticity: high positive correlations in the upper stratosphere, but moderately negative correlations in the lower stratosphere. This interesting pattern may be induced due to the polar vortex intensification in the stratosphere but the stratosphere-troposphere airmass exchange near the tropopause. This correlation analysis shows that the amount of TOC can be changed due to the multiple processes which are different vertically, therefore it seems necessary to consider this vertical difference more significantly for evaluating the role of TOC in terms of climate change.

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Characteristics of Surface Meteorology at Lindsey Islands, Amundsen Sea, West Antarctica

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Investigating warming in West Antarctica is important to understand and predict mass balance changes of the ice sheet. However, better understanding of the extent and rate of warming across West Antarctica through atmospheric processes has been limited by the lack of ground-based meteorological measurements. An automatic weather station (AWS) was set up at Lindsey Islands, the Amundsen Sea of West Antarctica, in 2008 and operated for about seven years. The measured variables at the site showed high inter-annual variability, particularly in winter seasons. Even though the site is under the strong influence by advection of cold air from inland ice sheet, the longitudinal shift of the center of the Amundsen Sea Low also results in much lower temperatures, especially in winter seasons, through cold advection from the south. The measured data showed good agreement with ERA-Interim and ERA5 reanalysis data, despite a large negative bias in wind speed. According to the ERA-Interim reanalysis data, there were no significant trends in seasonal averaged temperature from 1980 to 2014 except for significant trends of pressure and wind speed in autumn ($p < 0.05$), even though the interpretation of the trend requires caution. The seasonal correlation coefficients (R) of monthly averaged temperature (T) and pressure (P) between the study site and three neighboring AWS sites in the coastal area were high ($R > 0.8$ for T and $R > 0.92$ for P) and up to 0.76 for P and 0.72 for T at an inland site ~820 km away from the study site.

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What can stratospheric aerosol injection geoengineering do for Antarctic ice mass loss - lessons from Greenland

John Moore[1 †]

Geoengineering by stratospheric sulfate aerosol injection might slow ice sheet melting and sea level rise by reducing summer temperature and insolation, however such schemes would also reduce precipitation and affect large scale climate drivers such as the Atlantic Meridional Over-turning Circulation (AMOC). In contrast to Greenland, where surface melting accounts for about half of present-day mass loss, Antarctica has little runoff, despite a larger seasonal melt area than Greenland. We analyzed polar climates simulated by four Earth System Models running the GeoMIP stratospheric sulfate aerosol injection experiment G4 and the RCP4.5 and RCP8.5 greenhouse gas scenarios. G4 follows RCP4.5 greenhouse gas forcing but also includes injection of 5 Tg y-1 of sulfate aerosol into the lower stratosphere. Greenland is less responsive to G4 geoengineering than the mountain glaciers in Asia, where about 30% o melting is removed. In Greenland there is a 20% reduction in runoff under G4 relative to RCP4.5, while under RCP8.5 it is increased by 17%. This is because of changes in ocean heat transport to the Arctic in combination with reductions in mean near-surface air temperature, snowfall and downward longwave radiation. The mechanism is through weakened AMOC, increased Arctic sea ice concentration, reduced low level cloud all leading to surface cooling of the ablation zone. In Antarctica ice dynamics dominates mass loss. As with Greenland in the next century or two, it is ocean heating that will drive melt rates at the grounding lines of large outlets. An ice dynamics model that simulates glacier retreat driven by ocean temperatures and surface runoff suggests 15% lower Greenland ice losses under G4 than RCP4.5.

But in Antarctica changes in ocean temperatures at the grounding line are much less well-understood than those around Greenland. Model studies show larger differences across-models than between scenarios. We would expect that changes in Southern Ocean circulation would be affected by changes in sea ice and clouds that would be altered under aerosol injection. If surface temperatures continue to warm then disintegration of ice shelves via hydro-fracture processes as occurred on the Peninsula may also start to affect critical ice shelves further south.

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Potential effect of air pollution from the subtropical Southern hemisphere to Antarctica: spatiotemporal patterns of AOD, CO, NO2, and HCHO revealed by satellite observations

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Antarctica had been known to be unaffected by external influence due to the topographic and meteorological characteristics, but recent studies have reported that contamination from mid-latitudes can affect Antarctica. To assess the impact of air pollution emitted in southern hemisphere mid-latitudes and transported to Antarctica, we investigate the climatological mean and temporal trends in aerosol optical depth (AOD), carbon monoxide (CO), nitrogen dioxide (NO2), and formaldehyde (HCHO) columns using satellite observations. Moderate Resolution Imaging Spectroradiometer (MODIS) AOD, Measurements of Pollution in the Troposphere (MOPITT) CO, Ozone Monitoring Instrument (OMI) NO2 and HCHO level 3 data from 2005 to 2016 were used. Generally, all these measurements exhibit sharp peaks over and near the three inhabited continents: South America, Africa, and Australia. This pattern indicates the large emission effect of anthropogenic activities and biomass burning processes. High AOD is also found over the Southern Atlantic Ocean, probably because of the sea salt production driven by strong winds. Since the pristine Antarctic atmosphere can be polluted by transport of air pollutants from the mid-latitudes, we analyze the 10-day back trajectories that arrive at Antarctic ground stations in consideration of the spatial distribution of mid-latitudinal AOD, CO, NO2, and HCHO. We find that the influence of mid-latitudinal emission differs across Antarctic regions: western Antarctic regions have relatively more back trajectories from the mid-latitudes, while the eastern Antarctic regions do not show large intrusions of mid-latitudinal air masses. This suggests that pollutants from South America and Africa could be transported to Antarctica. Finally, we estimate the long-term trends in AOD, CO, NO2, and HCHO during the past decade. While CO shows a significant negative trend, the others show overall positive trends. Seasonal and regional differences in trends are also discussed.

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Two leading modes of Antarctic surface temperature and their contributions to Antarctic surface climate change

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Recent multi-decadal Antarctic surface climate change is clearly manifested by greater warming trends in the Antarctic Peninsula and West Antarctica, compared with East Antarctica. By using multiple observations and climate model simulations, we propose two leading modes of Antarctic surface temperature mainly contribute to the east-west asymmetric surface climate change. The first mode shows the surface temperature increase of the whole Antarctic continent, while the second mode displays the opposite temperatures between west and east Antarctica divided by the Transantarctic Mountains. The corresponding principle components from recent Antarctic surface temperature reconstruction dataset indicate that both modes become stronger during recent multi-decades, resulting in substantial warming over Antarctic Peninsular and West Antarctica and weak surface temperature change over east Antarctica. Additionally, long-term datasets show that global scale forcing factors have solid contribution to the first mode but little contribution to the second mode, suggesting that the current east-west asymmetry of Antarctic climate change can be natural origin.

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30-YEAR CLIMATOLOGY OBSERVED AT KING SEJONG STATION, ANTARCTICA

Sang-Jong Park †, Tae-Jin Choi, Bang-Yong Lee, Seong-Joong Kim

King Sejong Station (KSJ) is located on the King George Island, north off the Antarctic Peninsula at about 62.23S, 58.79W. Because KSJ is located at polar front zone, the station experiences frequent passage of cyclonic systems with very strong wind and overcast sky. Variation of surrounding large-scale circulations might affect polar front then weather conditions observed at KSJ. In that respect, KSJ offers a good opportunity to monitor atmospheric activity of Antarctica.

Regular meteorological observation has been made at KSJ (WMO Index No. 89251) since February 1988 to provide weather information for field activities as well as to study Antarctic climate. While the meteorological data has served well enough for station operation, the 30-year data from 1988 to 2017 inevitably contains some errorneous values due to sensor or system failure. There is also human errors in observations of cloud, weather phenomenan, snow etc. as well. Recognizing these kind or errors, we have carried out thorough quality control on the 10-minute raw AMOS (Automatic Meteorological Observation System) data to filter out doubtful values. Then daily statistics of AMOS data were compared to monthly weather reports (MWR) which were compiled by a meteorologist in each year. From this comparison, we could detect some additional erratic values in AMOS and/or MWR and correct as possible.

Using the quality-controlled meteorological data, we have studied various climatology of variables such as air temperature, wind, atmospheric pressure, precipitation, snow, solar radiation, cloud amount at the King Sejong Station. From 30-year data, mean annual temperature is -1.7 ℃, wind speed is 8.0 m/s, sea level pressure is 990.5 hPa. Interestingly, it was found that annual temperature recovered warming trend since 2010 contrary to cooling trend between 1999 and 2010. It was also noted that mena wind speed showed weaking trend since 2010 and cloud amount showed increasing trend.

In the presentation, mean and extreme values will be given for other variables. In addition, seasonal and monthly statistics will be presented.

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The Linkage between the Antarctic Sea Ice Extent in Indian Ocean sector and the Indian Summer Monsoon Rainfall

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Teleconnection between the variability of the Antarctic Sea Ice Extent (AnSIE) and the tropical climate has been extensively investigated. This study examines the interannual relationship between the variability of sea ice extent in the Indian Ocean (SIEIO) sector (20º–90ºE) and Indian summer monsoon rainfall (ISMR) under the influence of the Mascarene High (MH). SIEIO in high (HIP) and low (LIP) ice phase years during April-May-June (AMJ) appeared to have a significant correlation to ISMR in the Peninsula India region during June-July-August-September (JJAS), with correlation coefficients of 0.51 and 0.71, respectively. Composites of mean sea level pressure (MSLP), 500 hPa geopotential height, and 850 hPa wind anomalies during HIP and LIP also showed that there was a relationship between the SIEIO and the MH, revealing that HIP and LIP correspond respectively to the strengthening and weakening of the MH as well as increases/decreases in ISMR. During the respective HIP and LIP years, positive and negative MSLP anomalies were found respectively, particularly over the MH region associated with the eastwards and westwards shifts of its center from the normal locations. Similar features were also observed at 500 hPa geopotential height anomalies. In addition, 850 hPa wind flow illustrated strong anti-cyclonic and cyclonic anomalies in the MH region, which lead to corresponding strong and weak southwesterlies and thus respective positive and negative ISMR anomalies. Hence, a positive MH anomaly was associated with more ISMR.

A340

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Characteristics of Atmospheric Boundary Layer at the Jang Bogo Station, Terra Nova Bay, East Antarctica in Summer

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Better representation of atmospheric processes in the lower atmosphere are critical for weather forecast and climate change study by using numerical models. The reliability of the numerical models is not secured enough in the Arctic and Antarctic regions because the parameterizations of the atmospheric boundary layer (ABL) processes are mainly based on observations at lower latitudes (Kay et al., 2011; Deser et al., 2010; Boe et al., 2010) where environmental conditions are significantly different from those at polar regions with glaciated surface, sea ice or long-term white and polar nights. However, observational research have been conducted to better understand the processes in ABL in Antarctica and improve the ABL parameterization scheme (Argentini et al., 2005; Lin et al., 2009; Qu et al., 1997; Genthon et al., 2010) at some areas by using a variety of tools such as radiosonde, high-rise towers, LIDAR, atmospheric modeling and etc. At Dome C Station, which has many sunny days and no strong winds, located in the inland plateau of the East Antarctica, ABL depth was observed at 200~400m (Argentini et al., 2005). In Adeli land on the coast of the East Antarctic, the depth of ABL was observed as 50~600m, where the katabatic wind are strong. At Ross Ice shelf and South pole, ABL depth was observed to be less than 800m (Cassano, 2014) and less than 200m in austral summer season (Neff et al., 2007).

In this study, we will show the characteristics of vertical structure in the ABL including ABL depth in summer using radiosonde data from autosonde installed at Jang Bogo station (JBS, 74° 37'S, 164° 13'E), Terra Nova Bay, East Antarctica in 2014. Radiosonde measurements at the station was supposed to be made during non-summer season since measurements at the Mario-Zucchelli Italian station, 10 km away from the Jang Bogo station have been carried in summer season. But radiosonde measurements were made around 00UTC to test the autosonde performance and compare its profiles from those from the Italian station for two weeks in December, 2014.

The JBS is located at coastal area on Terra Nova Bay, which is affected by atmospheric movements of various sizes, including strong katabatic winds that are intermittently blowing from nearby glaciers, medium-sized low-pressure generated by nearby areas and continuous repetition of movement and extinction of various low-pressure systems in coastal areas of Antarctica (Kwon et al., 2016). The surface at the Station is fully exposed during summer period and the front sea is fully open short term in summer season. Toward inland, the area is covered with thick ice sheet, indicating complicated surface characteristics over which wind experience with blowing from inland to the sea. Annual mean temperature and wind speed are –15.2 ℃ and 4.4 m/s. Intermittently strong winds with > 30 m/s come from northwest. Dominant wind direction is west to northwest, however, in summer wind from northeast is dominant with weak wind speed.

To analyze profiles of potential temperature, humidity and wind from radiosonde, sampled data were interpolated at intervals of 10 m within 1 km. During this period, air temperature at 1.5m ranged from –4.4 to 5.5 ℃. Wind speed at 10 m was in the range of 0.2 to 15.5 m/s and dominant wind direction was northeast. Based on preliminary analysis, mainly based on potential temperature gradient with height, ABL height was evaluated to be 100 ~ 600m on clear days, showing a similar depth found in Adelie land located on coastal area, East Antarctica. However, we could not evaluate the ABL height due to unclear profile of potential temperature on several days, likely depending on trajectories of radiosonde. In the presentation, we will show the ABL characteristics in summer in detail including the measurements conducted during Year Of Polar Prediction in the Southern

Hemisphere (YOPP-SH).

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Session19: Tropical-Polar teleconnection and Antarctic climate change

Impact of the Madden-Julian oscillation on Antarctic sea ice

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The influence of the tropical Madden-Julian oscillation (MJO) on Antarctic sea ice extent has not been explored. This study identifies the intraseasonal variability of the sea ice extent, induced by the MJO, and its physical mechanism. During austral winter, the sea ice extent anomaly exhibits considerable melting and freezing as the MJO evolves. Numerical experiments and the Rossby wave theory show that the high-latitude circulation anomalies in response to the MJO are responsible for the sea ice change. The MJO-induced Rossby waves propagate into the Southern Hemisphere through the northerly ducts over the western Indian Ocean–central Africa and the Maritime Continent. The MJO-induced circulation anomalies, reaching high latitudes, lead to anomalous meridional temperature advection, causing the sea ice extent to decrease and increase. The time difference between the meridional wind and sea ice anomalies is ~5 days. As the MJO moves, the sea ice extent anomaly also exhibits eastward-migrating behavior. Strong sea ice melting in the total anomaly is also synchronous to the evolution of the MJO, suggesting the practical usefulness of the location of the MJO for the prediction of the sea ice.

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The future projection of ice sheet melting and sea level rise under the RCP scenarios

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Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, and global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate. Warming from anthropogenic emissions from the pre-industrial period to the present will persist for centuries to millennia and will continue to cause further long-term changes in the climate system, such as sea level rise, with associated impacts. The IPCC projected 53.5~91.4 cm of sea level rise by 2100, but this projection did not include a significant contribution from the Antarctic Ice Sheet (IPCC AR5, 2013). Therefore, future IPCC estimates will almost certainly be revised upwards. Recently, a series of studies pointed out the collapse of the Antarctic ice sheet is accelerating and may have already passed a tipping point based on new observations and model simulations. Antarctica is the main driver of the risk of really high sea level rise, so we really need to understand what's happening there. Under these circumstances, we produced the future projections of ice sheet melting and sea level rise based on the IPCC RCP(Representative Concentration Pathway) scenarios from 17 CMIP5 CGCMs targeting the Drygalski Ice Tongue and David Glacier, East Antarctica. The 2-dimensional (2-D) shallow shelf approximation model (MacAyeal, 1989), which is implemented in the Ice Sheet System model (ISSM) (Larour et al., 2012) is used. From 1950 to 2100, 70 ensemble experiments with RCP 4.5 scenarios and 43 ensemble experiments with RCP 8.5 scenarios are conducted. The changes in ice velocity and ice thickness are analyzed and global sea level changes from this region are projected. The globla and regional implication of these changes are investigated.

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Session20: Evolution of the biota of West Antarctica: a Gondwana perspective

Otolith edge chemistry reveals the role of water mass in structuring Electrona antarctica population in the Antarctic Circumpolar Current system

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Electrona antarctica is the dominant mesopelagic fish species in the Southern Ocean and the most common myctophid occurring south of the Antarctic Polar Front. It is related to the Circumpolar Deep Water (CDW) transported by the Antarctic Circumpolar Current (ACC) and modified CDW (MCDW) associated with the Antarctic Slope Current (ASC). In combination with the regional-scale ecosystem survey at the south of the Kerguelen plateau (K-Axis survey), Electrona antarctica samples were collected from the ACC system, including Antarctic Circumpolar Circulation Front (SACCF), Southern Boundary (SB) and the Fawn Trough Current (FTC) of the Princess Elizabeth Trough. The otolith chemistry from the nuclei and edges were examined to understand the role of water mass and front in structuring the population of this species. The results indicated a significant differences occurred in Me·Ca ratio between nucleus and edge of the otolith. Multivariate Analysis of Variance (MANOVA) was used to examine the differences in otolith chemistry of E. antarctica between frontal zones of the SACCF, SB and FTC. The elemental fingerprints in both the otolith nuclei, which deposited during the early life of E. antarctica, and the edges, which deposited in the recent period, demonstrated there are no heterogeneity. Fronts in the eastern-flow ACC system cannot distinguish the populations of this species. However, the otolith chemistry of E. antacctica indicated significant differences between water masses, and particularly the Lower Circumpolar Deep Water (LCDW) and MCDW played an important role in separating populations of this species.

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Session20: Evolution of the biota of West Antarctica: a Gondwana perspective

Variation in fatty acid composition and diet of Antarctic krill (*Euphausia superba*) in the Bransfield Strait during autumn 2017 and 2018

Bo Deng , Guoping Zhu †

Antarctic krill (*Euphausia superba*) occupies a critical position in the energy flow and material circulation of the Southern Ocean ecosystem, and is an extremely important biological resource in the Antarctic waters. However, the diet of this species varies regionally and temporally. In order to investigate the differences in fatty acid composition and diet of Antarctic krill in the autumn of 2017 and 2018, this study examined the fatty acid composition of Antarctic krill from April to May 2017 and 2018, and inferred the diet of this species using marker fatty acids. The results showed that 32 and 30 types of fatty acids were detected from the individuals in 2017 (standard length 32.56 to 52.47 mm) and 2018 (standard length 32.99 to 51.01 mm), respectively, with higher levels of C14:0, C16:0, C18:1n9c, C20:5n3 (EPA) and C22:6n3 (DHA) occupied in the fatty acid composition. Among marker fatty acids, highest content of C16:0, and the significant high ratio of EPA/DHA (>1, diatom-indicated) and C16:1n7/C16:0.

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The paleontological heritage of Fossil Hill Formation on the King George Island. An Early Eocene Lagerstätten from Antarctic?.

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Throughout the 300 million years covering the Palaeozoic, Mesozoic and Cenozoic, the fossil record exposes high latitudes biotas, as those find in Antarctica. This continent is actually covered by permanent ice and snow in nearly 98% of its surface. Some interesting palaeontological areas remain protected by the Antarctic Specially Protected Area (ASPA) designation, which safeguards outstanding environmental, scientific, historic, aesthetic or wilderness values, any combination of them, or the scientific research. At present, six areas in Antarctica are protected due to its paleontological component. Sites with high concentration and good preservation of fossils correspond to those from South Shetland Islands and James Ross Basin, which include fossils from Jurassic to the Neogene periods.
Ichnofossils are abundant in the case of invertebrates; however, ichnofossils of vertebrates are extremely rare, and there are only two informed places in Antarctica where they can be found: the Early Triassic Fremouw Formation, in the Transantarctic Mountains, and the Eocene Fossil Hill Formation from King George Island, South Shetland Islands.
The Antarctic paleontological heritage applied to fossils or sites with scientific and educational value, providing a unique insight into natural history and evolution of the life on Earth. Improve the accessibility to Antarctica would allow us to recognized the need for distinguish, protect, and manage sites there with paleontological heritage.
Knowing that Conservation Lagerstätten (Konservat-Lagerstätten) sediments are those that preserve quality rather than quantity of organic remains, and that are usually restricted to sites with peculiar preserve conditions, even to conserve soft tissue of animals and plants in incredible detail, this work present the case of Fossil Hill site from King George Island, South Shetland Islands (Antarctic Specially Protected Area, ASPA, No. 125), arguing the evidence recovered there would allow the recognition of the site as a high latitude ichnofossil Lagerstätten.
In order to achieve the ASPA goals with respect to protected areas within paleontological values, it is necessary to know its paleontological heritage. Thus, the integrity, fidelity and types of fossils from Fossil Hill, proposed with a Fossil Lagerstätten category, would provide insights into key biological events in the Antarctic natural history.

INTRODUCTION

Antarctic palaeontology is distinctive and very informative tool; throughout the 300 million years covering the Palaeozoic, Mesozoic and Cenozoic, the fossil record exposes high latitudes biotas. Antarctica actually is a continent covered by permanent ice and snow in nearly 98% of its surface. When logistic allows it, access to palaeontological sites is difficult: It is possible to access them only in Austral summer and in ice free-areas. This is why the most studied sites correspond to those near permanent stations. Some interesting palaeontological areas remain protected by Antarctic Specially Protected Area (ASPA) designation, which safeguards outstanding environmental, scientific, historic, aesthetic or wilderness values, any combination of those values, or ongoing or planned scientific research. At present six areas are protected due to its paleontological component (see Antarctic Protected Areas Database: ASPA 125, 126, 138, 143, 148 and 174). Sites with high concentration

and good preservation of fossils correspond to those from South Shetland Islands and James Ross Basin, which include fossils from Jurassic to the Neogene periods, mainly marine reptiles, avian and non-avian dinosaurs, mammals, invertebrates, microfossils, trunks, leaves and ichnofossils (Poole et al., 2001; Francis et al., 2008; Dutra & Batten 2002; Leppe et al., 2012; Reguero et al., 2013). Ichnofossils are abundant in the case of invertebrates; however, ichnofossils of vertebrates are extremely rare, and there are only two informed places in Antarctica where they can be found: the Early Triassic Fremouw Formation, in the Transantarctic Mountains (MacDonald et al. 1992), and the Eocene Fossil Hill Formation from King George Island, South Shetland (Covacevich & Lamperein, 1972).The Antarctic paleontological heritage is applied to fossils or sites with scientific and educational value, providing a unique insight into natural history and evolution of life on Earth. Improve the accessibility to Antarctica would allow us to recognized the need for distinguish, protect, and manage sites with paleontological heritage.

Fossil Lagerstätten sites are defined as rock bodies unusually rich in palaeontological information, either in a quantitative or qualitative sense (Seilacher, 1985). Conservation Lagerstätten (Konservat-Lagerstätten) sediments are those that preserve quality rather than quantity of organic remains, and this concept is usually restricted to those rare instances where peculiar preserve conditions have allowed even the soft tissue of animals and plants to be preserved, often in incredible detail: skin, hair, feathers, muscle tissue, cells with nuclei, ovaries with eggs, and even blood (Nudds & Selden, 2008).

In this work we present information about the fossil discovered in the Fossil Hill site in King George Island, South Shetland Islands, arguing the evidence recovered there would allow the recognition of the site as a high latitude ichnofossil Lagerstätten.

METHODOLOGY

The Fossil Hill site is an small elevation above sea level on Fildes Peninsula, King George Island, South Shetland Islands, Antarctica (62°10'50''S–62°11'28''S, 58°55'27''W–58°56'38''W; Fig. 1), located 2 km south-west of the permanent Chilean Scientific Station "Prof. Julio Escudero" and near the Chinese "Great Wall" Station. Recent $^{40}Ar/^{39}Ar$ datings of Fildes Peninsula sediments suggests a Luthetian Ypresian (Early Eocene) age (56.38 ± 0.2 and 54.66 ± 0.56 Ma; Gao et al. 2018). This ichnological site has been known since the end of the 1960s, mainly due to its abundant and well-preserved palaeobotanical and ichnofossil remains. As a result of the unusually rich fossil content, the area was originally proposed by Chile as a Specially Protected Area No. 12 in 1966, modified in 1968, and re-designated as Site of Special Scientific Interest No. 5 in 1975. In 2002 was renamed as Antarctic Specially Protected Area (ASPA) No. 125. The main objectives of this ASPA are to protect the paleontological values because of their uniqueness and the ease with which scientific research can be conducted in the area; to facilitate non-destructive palaeontological and geological scientific research in it, and to promote the understanding, education and awareness about the values of this remarkable area.

RESULTS

The Fossil Hill assemblage includes diverse floral remains (Li Haomin & Zhou, 2007; Poole et al., 2001; Fontes & Dutra 2010; Jacques et al., 2014) and ichnofossils referred to invertebrates (Yang & Shen, 1999; Verde et al. 2017; Uchman et al. 2018), six types of birds (Covacevich & Lamperein 1969, 1970, 1972; Covacevich & Rich 1982; Li & Zhen 1994; Mansilla et al., 2012) and an isolated mammal footprint (H.M.V work in progress).

Vertebrate ichnofossils include: 1) Large tridactyl footprints assigned to ratite or a phororhacoids with skin marks. 2) Wading birds assigned to *Uhangrichnus* genus, with interdigital web and presumable soft tissue preservation. 3) Well preserved slender and short anisodactyl bird trackways assigned to *Gruipeda*, with feeding traces around. 4) A tridactyl birds with short-thick digits and distinct claws assigned to *Avipeda* genus. 5) A tridactyl bird with enlarged distal part of the digits assigned to *Fildesichnus* genus. 6) A morphotype with curvated digit imprints, II and IV, and large hallux impression, assigned to *Alaripeda* genus. Also has been recovered an unique and single

record of an 20mm isolated flight feather, with a microscope hooklets preserved (Mansilla et al., 2014), and an isolated mammal track of a small carnivore, with extremely short or retractable claws, reminding a feline sole pad.
All fossil came from very fine grain (0.004–0.062 mm) red-brown fangolites that reach 2 to 5 centimetre thickness. It has laminate structure given by the intercalation of pelitic facies with fine to medium grain psamitas. Thin section shows a fine grain clastic texture with good selection composed mainly of subrounded to subangular feldspars altered to clays and sericite, rounded andesitic volcanic lithics, strongly oxidized and subordinately pyroxenes and opaque minerals in a clay matrix and mosaic ceolithic cement.

DISCUSSION AND CONCLUSSIONS

Terrestrial Eocene outcrops in Antarctic are uncommon (Reguero et al., 2013); exclusive are the Fossil Hill assemblage, which are ascribed to the *Mermia* or *Scoyenia* ichnofacies (Buatois & Mángano, 1995), or a transition between them, indicating fluvial and lacustrine environment (Mansilla et al. 2012, Verde et al. 2017). Fossil Hill from Fildes Peninsula on King George Island exhibits the unique site with Early Eocene vertebrate ichnofossils *in situ* from the continent.
The high-quality preservation of fossils and the sedimentological characteristic of the site support a low energy condition and rapid burial, which facilitate the preservation of fragile structures, like feathers. Evidence of volcanic activity at Fossil Hill (Shen, 1994) and high levels of rain revealing summer monsoon (Jacques et al., 2012); contribute to high sedimentation rates and lead to rapid burial of organic debris, creating a perfect preservational scenario during taphonomy.
In order to achieve the ASPA goals with respect to protected areas in Antarctic with paleontological values, it is necessary to know the paleontological heritage of sites. Thus, the integrity, fidelity and types fossils from Fossil Hill, allow us to propose a Fossil Lagerstätten category for this zone, which provide insights into key biological events in Antarctic natural history. Further studies are necessary in the Area, in order to protect and notify properly about the importance of this site, due its easy accessibility, which make vulnerable to souvenir collectors.

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Using Very- and Ultra-High resolution Digital Elevation Models in Antarctic Biological Research

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Digital elevation models (DEMs) are frequently used in landscape and evolutionary ecology to understand individual species distribution, relative genetic variation, and subsequent habitat suitability (Kozak, Graham & Wiens 2008). Despite the incorporation of topographic analysis using digital elevation models (DEMs) being commonplace, most studies have used courser DEMs or 10m resolution or greater. The increasing availability of very- and ultra-high resolution (VHR and UHR respectively) is enabling researchers to accurately estimate topographic surface derivatives on a fine-scale, but suitability of such applications at such scales still requires critical evaluation. In biological studies, VHR and UHR DEMs can provide valuable information on covariates impacting modelling of species distribution, in response to global changes, especially in response to global change, in particular the ability to identify microrefugia (Dobrowski 2011).

Further, In this effort, we used imagery of several penguin colonies collected throughout the Antarctic peninsula by both commercial high-resolution satellites and unmanned aerial vehicles (UAV). Using this imagery, we derived VHR and UHR DEMs at various spatial resolutions (e.g. 50 cm, 2m, 8m, 10m, etc.) to assess (1) variance in derived topographic features (e.g. slope, aspect, surface wetness, etc.) within and between sensor models (commercial vs. UAV); and (2) discuss the relative suitability of DEMS as different spatial resolutions in research applications, using ecology of Adelie penguin colonies as a case study.

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The Cytological, Microbiological and Ophthalmic Evaluation of Ocular Surface Samples Taken from Penguin Species of the Antarctic Peninsula: Preliminary evaluation of the results belong to ten eye swabs

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The study aims to assess the efficiency and usability of ocular surface cytology, in terms of cellular and microbiological diagnosis, in penguins belonging to the *Pygoscelis* genus, and to establish reference values by means of ophthalmic tests. The ophthalmic and ocular surface sampling was performed in the South Shetland Islands and in the northern part of the Antarctic Peninsula. Adult (n = 87) and chick (n = 13) penguins were sampled from all island.

The first part of the study involves the collection of ocular surface cell samples by exfoliative cytology from penguin species of the genus *Pygoscelis*, which inhabit the islands of the Antarctic Peninsula, namely, the adelie penguin (*P. adeliae*), chinstrap penguin (*P. antarcticus*) and gentoo penguin (*P. papua*). For examination of cytological samples, impression and brush cytology techniques were used. Cell specimens collected by brush cytology were used for the evaluation of cell morphology and the presence of bacteria, fungi after undergoing cytospin centrifugation. Cytological changes were evaluated under light microscopy according to Nelson's grading system. Impression cytology was used as a simple method for the sampling and counting of conjunctival goblet cells. Due to the adhesion capability of the sampling device, impression cytology were used to collection of the most superficially located cells on the ocular surface. Corneoconjunctival surface epithelial cells and sporadic inflammatory cell infiltrations were observed. High rates of goblet cells were noted in some of the preparations. Microscopic examination of preparations revealed superficial, intermediate and basal epithelial cells organized in layers. Degenerate epithelial cells, fibrine, neutrophil leukocyte, bacteria and fungi, cellular debris and mucus were detected on eyes.

The second part of the study objective of this study is to investigate the bacterial ocular flora of healthy penguins in Antarctica. The bacterial flora of the eyes of penguins found in Lion Ramp Island was investigated. For this purpose ten eye swap samples were analysed. The samples were directly inoculated onto tryptic soy agar containing 5% sheep blood. The inoculated petri dishes were incubated at 37 ^{0}C under aerobic and microaerobic conditions for 24-48 hours. Furthermore, the swabs were also placed into brain-heart infusion broth and incubated under aerobic and microaerobic conditions for 24 h. The cultures grown were inoculated onto tryptic soy agar containing 5% sheep blood and the inoculated petri dishes were further incubated at same conditions mentioned above. Then the colonies were examined macroscopically (size, colour, odour, haemolysis, etc.) and microscopically. Each different colony were subcultured on sheep blood agar to obtain pure cultures. Phenotypic (including Gram staining, catalase, oxidase, motility and carbohydrate fermentation tests) and molecular test (16S rRNA sequence analysis) were used for

the identification of the isolates recovered.

As a result, a total of 18 isolates were obtained from 6 (3, 2, 5, 1 and 4 isolates from each sample respectively) of 10 samples collected. Isolates were identified as *Psychrobacter* sp. (9 isolates from 5 samples), *Psychrobacter sanguinis* (2 isolates from 2 sample), *Corynebacterium* sp. (2 isolates from 2 sample), *Corynebacterium sphenisci* (1 isolate from 1 sample), *Psychrobacter phenylpyruvicus* (1 isolate from 1 sample), *Brachybacterium* sp. (1 isolate from 1 sample), *Moraxella osloensis* (1 isolate from 1 sample) and *Pseudoarthrobacter oxydans* (1 isolate from 1 sample).

The third part of the study tear production and intraocular pressures (IOPs) were determined in total 100 penguins from the Yelchoo, Base General Bernardo O'Higgins, Harmony point Lion ramp, Ardley protected area. Tear production was measured by Schirmer tear test, and IOP was measured with a TonoVet rebound tonometer. This is the first study, to our knowledge, investigating tear production and IOP in *Pygoscelis* penguins and establishes valuable reference intervals for this species.

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Session21: Geomicrobiology of Antarctica and Patagonia

Preliminary results of a geomicrobiological study in the Madre de Dios archipelago

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Madre de Dios archipelago (49-52°S) is located in the Region of Magallanes and Chilean Antarctica, in Chile. It is made up of 54 islands dominated by a karst environment and a sub-polar oceanic climate, with winds that regularly exceed 100 km/h and rainfall grater than 1000 mm per month. During the expedition "Ultima Patagonia 2019" organized by Centre Terre, samples of rocks and speleothems from different types of cavities were taken.
These confirmed different levels of climatic exposure, which generated a relatively stable environment for the activity of microorganisms. The acidity of the waters coming from these cavities oscillates between 7 and 9, which allows to classify the waters as basic solutions, with unfavorable conditions for life. However, in the field it was possible to observe moonmilk and other carbonated forms in which bacterial activity its presumed. Based on the identification of textures that are indicative of microbial activity, it is possible to mention as a preliminary result, that the cavities visited during the expedition and from which the samples were taken,
meet the stable conditions for the activity of microorganisms. For this reason we are already analyzing the microorganisms in order to identify them.

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Distinctive microbial assemblages and their ecological function in permanently ice-covered lakes of the Dry Valleys, Antarctica

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Permanently ice-covered lakes in the McMurdo Dry Valleys of Antarctica have been paid attention for their physical, chemical and biological significances. We carried out the comparative study on bacteria community structures and biogeochemistry with certain depths in five lakes. All lakes showed more homogenous bacterial assemblages in epilimnion, whereas a certain lake had distinctive ones in hypolimnion. In Lake Bonney, 30 m depth of the East and West Lobe was dominated by two distinct Firmicutes classes. While lineages of Cholobi are detected only at the depth of 18 m in Lake Miers, candidate division WM88 occurred at 15 m depth of Lake Fryxell. Furthermore, Lake Fryxell was dominated by various uncultured bacterial lineages belonging to not only well known Bacteroidetes, Actinobacteria and Planctomycetes but also candidate divisions, so-called 'microbial dark matter' including JS1, WM88 and SAR 406. To understand the implication of their ecological roles in this lake, shotgun metagenomics were conducted. This talk will present to uncover unexpected metabolic features linked to the microbial ecological function in this hypersaline ecosystem, Antarctica.

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Mechanistic insight into 3-methylmercaptopropionate metabolism and kinetical regulation of demethylation pathway in marine dimethylsulfoniopropionate-catabolizing bacteria

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The vast majority of oceanic dimethylsulfoniopropionate (DMSP) is thought to be catabolized by bacteria via the DMSP demethylation pathway. This pathway contains four enzymes termed DmdA, DmdB, DmdC and DmdD/AcuH, which together catabolise DMSP to acetylaldehyde and methanethiol as carbon and sulfur sources, respectively. Whilst molecular mechanisms for DmdA and DmdD have been proposed, little is known of the catalytic mechanisms of DmdB and DmdC, which are central to this pathway. Here we undertake physiological, structural and biochemical analyses to elucidate the catalytic mechanisms of DmdB and DmdC. DmdB, a 3-methylmercaptopropionate (MMPA)-coenzyme A (CoA) ligase, undergoes two sequential conformational changes to catalyze the ligation of MMPA and CoA. DmdC, a MMPA-CoA dehydrogenase, catalyzes the dehydrogenation of MMPA-CoA to generate MTA-CoA with Glu435 as the catalytic base. Sequence alignment suggests that the proposed catalytic mechanisms of DmdB and DmdC are likely widely used by bacteria using the DMSP demethylation pathway. Analysis of the substrate affinities of involved enzymes indicates that Roseobacters kinetically regulate the DMSP demethylation pathway to ensure DMSP functioning and catabolism in their cells. Altogether, this study sheds novel lights on the catalytic and regulative mechanisms of bacterial DMSP demethylation, leading to a better understanding of bacterial DMSP catabolism.

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Geomicrobiology studies at Union Glacier in the Ellsworth mountains: microbial survival in one of the most extreme environments in Antarctica

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The Union Glacier Chilean Camp is located in the Ellsworth mountains, at approximately 1000 km from the South Pole, with temperatures between -26 / -28 ºC during April-September and near -6 ºC in January. Close to this camp there are 3 sites from where we obtained soil samples (surface and 10 cm depth): 4 from Elephant Head, 7 from Rossman Cove and 2 from Charles Peak.
Mineralogical and elemental compositions of these soil samples were determined by means of XRD and SEM-EDS, respectively. XRD analysis of Rossman Cove samples revealed the presence of muscovite, quartz, plagioclase and potassium feldspar. Samples from Elephant Head presented calcite, dolomite and quartz. In the case of Charles Peak, quartz, muscovite, chlorite and plagioclase were determined. The elemental analysis revealed the presence of O, Si, Al, K, Mg, Na, Fe, Ca, Ti and S in Rossman Cove, O, Si, Ca, Al, K, Mg and Fe in Elephant Head, and O, Si, Al, Fe, K, Mg, Ca, Na and Ti in Charles Peak.
Also, several biological studies were performed. A total biological activity analysis using the colorimetric compound triphenyl formazan (TPF) revealed a scarce biological activity in all samples analyzed. However, an increase in the activity was observed when evaluated in presence of glucose, reflecting the activity of heterotrophic microorganisms, particularly in the surface soil samples from Elephant Head. The content of organic matter was evaluated and very low levels of N and C were determined (N: 0.006% - 0.015% and C: 0,032% - 0,048%). These values are lower than those previously determined by our group for samples obtained from the South Shetland Islands and were also lower than those reported in the Dry Valley.
Then, a total DNA extraction was performed. As expected, a minimal amount of total DNA per gram of soil was observed in all soil samples, a result that agrees with the scarce biological activity and the C/N % observed in all samples. This result also agrees with the adverse conditions present in the zone (low temperatures, absence of light and liquid water). The total DNA obtained was used to determine the abundance and diversity of bacteria present in each sample by sequencing of the 16s rRNA. The analysis of bacterial communities determined specific populations inhabiting the three zones tested, and also evidenced differences in bacterial community composition at different depth.
In addition, aerobic microorganisms capable to grow in heterotrophic media at 4, 10 and 22 oC were isolated. Bacteria belonging to Pseudomonas, Paracoccus, Lysobacter, Micrococcus, Bacillus, Kocuria, Arthrobacter and Plantibacter genera were obtained. When the soil of each sample was used as substrate to sustain bacterial growth, we were able to isolate 3 microorganisms that after several cycles were also capable to growth in heterotrophic conditions. These isolates present different phenotypic and genotypic characteristics and correspond to Arthrobacter agilis (2) and Arthrobacter parietis. Some of these isolates were highly resistant to freeze and thaw cycles, particularly when compared to other Antarctic isolates and lab strains. This novel characteristic is probably a consequence of the extreme conditions present in Union Glacier that involves the regular exposure to dramatic changes in temperature.
Our work represents the first Geomicrobiology study performed at the Ellsworth mountains and will contribute to understand how life develops in extremely harsh environments. By means of X-Ray microtomography we are currently analyzing the internal structure (density/porosity) of the minerals

present in the samples to determine if the structural characteristics of the mineral contribute to the survival and development of specific bacterial communities in Union Glacier. In addition, we are analyzing the RNA present in the samples to determine the expression of specific genes involved in the cellular response to the extreme conditions present in this zone.

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Bioprecipitation of calcium carbonate induced by bacteria isolated from regolith of Ellsworth Mountains

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The Ellsworth mountains are located in the central area of Western Antarctica, between the longitudes 78° - 87 ° W and latitudes 80 ° 30 ' - 77 ° 15' S. They are 350 km long and 80 km wide and are divided into two Mountain ranges by the Minnesota glacier: Sentinel in the north and Heritage in the south.
In geological terms, a stratigraphic sequence of 13 km is exposed in the Ellsworth Mountains, composed mainly of volcanoclastic rocks of ages ranging from the Lower Cambrian to the Permian. In this study we investigated the possibility that microorganisms isolated from regoliths collected in the near of the Union Glacier, in the Heritage Range, were able to precipitate calcium carbonate. All the samples were characterized geologically (chemistry, petrography and mineralogy of the components of the regoliths) and biologically (isolation of microorganisms).
The regolith samples were selected, which in the mineralogical analysis by X-ray diffraction showed the presence of calcium carbonate minerals (calcite and dolomite), in order to isolate the bacteria present in them. For this, three solid culture media were elaborated, in which the bacteria capable of precipitating calcium carbonate could grow, and at the same time delivered the nutrients and enough energy to induce such precipitation. These media are: B4 (enrichment medium for bacterial calcification), PCC (medium that allows the precipitation of calcium carbonate through urea hydrolysis), and BP (based on B4 medium, but with less nutrients). The media, arranged in Petri dishes, were inoculated with a solution of regolith and distilled water. In this way, the colonies that were subsequently isolated in other plates with the same growth media were obtained. All the plates were examined daily under an optical microscope in order to monitor the production of crystals up to 15 days after the isolates were obtained.
A total of 14 isolates were obtained among the three media, and of these, ten of them induced crystal precipitation, representing 71.4% of the bacteria that could potentially have precipitated crystals. Of the ten isolates that precipitated calcium carbonate, 9 were identified in the BP medium and 9 in the B4 medium, while in the PCC medium only 5 isolates induced crystal precipitation. The observation through the microscope revealed that the precipitation begins as a white spot, which then appears as a dark gray point in the center, followed by the growth of the calcium carbonate crystal. Different habits were recognized in crystals, mainly spherical, rhombohedral, tabular, pyramidal, globular and amorphous, and there may be more than one in the same isolate. Once 15 days had passed since the precipitation began, the crystals were removed from the plates. Based on the observation of each sample, those where the precipitation was highest and the crystals reached a size of at least 100 µm were chosen. According to this, three crystals were chosen under binocular microscope: one of rhombohedral habit, one spherical, and one botroidal, all belonging to samples of the BP medium.
Only the rhombohedral crystal, which exceeded 150 µm in length, could be analyzed correctly trough single-crystal X-ray diffraction.
After 136 reflections, the X-ray diffraction data established a hexagonal unit cell with the reticular parameters a = 4.88 Å, b = 4.88 Å, and c = 16.71 Å. The angles were α = 90º, β = 90º, and γ = 120º, with 345Å3 of cell volume, and a relation c / a = 3.42. These parameters were compared with

those present in the American Mineralogist Crystal Structure database and scientific papers, concluding that the crystal corresponds to calcite rich in magnesium of biogenic origin.

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Geomicrobiological transformations in Antarctic subglacial environments

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Groundwater systems, subglacial wetlands and hundreds of subglacial lakes exist below the ice sheets of Antarctica. These subice environments are proving to be diverse microbial habitats driven by unique geochemical and hydrological settings. Although thick glacial ice covers these systems, making sample acquisition logistically challenging and infrequent, recent airborne geophysical surveys and melt-probe expeditions have enabled detailed study of the subglacial biome below Taylor Glacier in the McMurdo Dry Valleys. The brine below the glacier is an iron-rich fluid that emerges at a dark red surface feature known as Blood Falls. This brine contains a viable, metabolically-active chemosynthetic microbial community that has been shown to respire iron oxides using reduced sulfur compounds as electron donors. Here I will present our recent culture independent and dependent work on the community ecology of this feature. Molecular analysis (i.e., metagenomic community analysis and whole genome sequencing of bacterial isolates) indicate that several chemosynthetic pathways are employed by this community; the Wood-Ljungdahl pathway is the most abundant. Physiological and genomic characterization of microbial isolates obtained from these samples reveal adaptations for growth at low temperatures and high salt concentrations, characteristics that reflect conditions in subglacial habitat below Taylor Glacier. Further, microbial isolates from this system can grow under anaerobic conditions using synthetic ferrihydrite as an electron acceptor. Analysis of mineral phases following these incubations reveals how microbes from the subglacial system form unique mineral phases both during growth and precipitation at the surface. Understanding how microbes facilitate mineral transformation below glaciers will inform the composition and potential impact of subglacial groundwater discharge into the Southern Ocean. These molecular and mineralogical findings also serve as biomarkers for the exploration of new subglacial ecosystems in Antarctica, aid in the interpretation of paleo-subglacial deposits and develop potential biomarkers for exobiological targets. Collectively these data suggest that despite extended isolation in icy darkness, microbial life persists and possibly thrives below the Antarctic Ice Sheet.

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Session22: Emerging Frontiers in Satellite Remote Sensing and Geoinformation in Antarctic Earth Sciences: Cross-disciplinary Advances

Mapping poorly exposed lithologies using Landsat-8 and ASTER satellite data in Antarctic Peninsula

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In this study, the applications of Landsat-8 and ASTER remote sensing data were investigated to extract geological information for lithological and alteration mineral mapping in poorly exposed lithologies in inaccessible domains. The north-eastern Graham Land, Antarctic Peninsula (AP) was selected in this study to conduct a satellite-based remote sensing mapping technique. A two-stage approach was adopted to distinguish pixel and sub-pixel targets in the remote sensing images at both regional and district scales. In the first stage, Continuum Removal (CR) spectral mapping tool and Independent Components Analysis (ICA) were applied to Landsat-8 and ASTER spectral bands to map poorly exposed lithologies at regional scale. The second step was established based on target detection algorithms such as Constrained Energy Minimization (CEM), Orthogonal Subspace Projection (OSP) and Adaptive Coherence Estimator (ACE) to ASTER shortwave infrared bands for detecting spectral features attributed to alteration mineral assemblages at district scale. Pixels composed of distinctive absorption features of alteration mineral assemblages associated with poorly exposed lithological units were detected by applying CR mapping tool to VNIR and SWIR bands of Landsat-8 and ASTER. Pixels related to Si-O bond emission minima features were identified using CR mapping tool to TIR bands in poorly mapped and unmapped zones in north-eastern Graham Land at regional scale. Anomaly pixels in the ICA image maps related to spectral features of Al-O-H, Fe, Mg-O-H and CO3 groups and well-constrained lithological attributions from felsic to mafic rocks were detected using VNIR, SWIR and TIR datasets of Landsat-8 and ASTER. ICA method provided image maps of alteration mineral assemblages and discriminate felsic to mafic lithological units with little available geological data for poorly mapped regions and/or without prior geological information for unmapped regions in northern and southern sectors of Oscar II coast area, Graham Land. Fractional abundance of alteration minerals such as muscovite, kaolinite, illite, montmorillonite, epidote, chlorite and biotite were identified in alteration zones using CEM, OSP and ACE algorithms in poorly mapped and unmapped terrains at district scale. The results of this investigation demonstrated the applicability of Landsat-8 and ASTER spectral data for lithological and alteration mineral mapping in poorly exposed lithologies and inaccessible regions, particularly using the image processing algorithms that are capable to detect anomaly pixels and sub-pixel targets in the remotely sensed images, where no prior information is available. In conclusion, a simple and robust satellite-based remote sensing approach for geological mapping in inaccessible and poorly exposed regions was established, which is comprehensively applicable for lithological and alteration mineral mapping in the Antarctic environments.

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Observing the Cryosphere with Next Generation GNSS-Reflectometry

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The cryosphere plays an important role in the global water cycle and is a major contributing component of the Earth system. Sea ice and ice sheet cover in particular are crucial components of the cryosphere, moderating global climate, influencing ocean and atmospheric circulation patterns, and affecting marine and terrestrial ecosystems. While many remote sensing techniques exist to study the Earth system and its properties, GNSS-reflectometry (GNSS-R), is expanding its range of applications. GNSS-R uses airborne and spaceborne instruments to receive the GNSS signals reflected off the surface of the Earth, creating a novel passive, bistatic radar configuration that requires deployment of only receiver hardware. The GNSS transmitters, which are funded and maintained by governments and third parties, are expanding in number, power and bandwidth. This allows the capabilities of GNSS-R to improve without the typical costs associated with dedicated remote sensing transceivers. These signals of opportunity are transmitted in the L-band, known to be transparent to precipitation and to penetrate both snow and ice, making it ideal for polar applications. Because of the reduced hardware requirement, the receivers can be placed on smaller satellites, allowing their affordable use in constellations that improve temporal sampling, while the large number of existing GNSS constellations can provide global coverage. In short, GNSS-R presents the unique features of cost effectiveness, synoptic sampling, and all-weather versatility. Recently published results from spaceborne GNSS-R instruments have demonstrated significant sensitivity to ice reflections. Ice sheet altimetry and draft measurements were achieved with a GNSS-R instrument onboard the TechDemoSat-1 (TDS-1) satellite. Using the 8-satellite Cyclone Global Navigation Satellite System (CYGNSS) constellation and the strength of GPS reflections, the coherent reflection properties of ice were used to detect and estimate sea ice coverage. However, neither of these existing GNSS-R satellite instruments have been optimized for cryosphere observations.

In this presentation, we are looking toward the future to understand how next generation GNSS-reflectometry (GNSS-R) remote sensing techniques can be applied to study and quantify aspects of the cryosphere, specifically by observing sea ice and ice sheet extent, height, thickness, and characterization. By taking advantage of cutting-edge improvements in the receiver's hardware and algorithms, measurements of cryosphere properties may be achieved with greater accuracy and precision than that of current GNSS-R techniques. These improvements include: (1) phase detection of the GNSS reflection which will enable phase altimetry; (2) adjustable coherent and non-coherent integration times leading to more precise control of spatial resolution; (3) dual frequency tracking, increasing bandwidth and further improving spatial resolution; (4) coherence detection, allowing the discrimination between coherent and incoherent reflections, which may enable differentiation between young and old sea ice; and (5) a dual polarization antenna, allowing polarimetric reflection measurements. These improvements have the potential to bring exciting new observations to cryosphere studies, enabling researchers to further understand the changing cryosphere.

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BedMachine Antarctica v1: a new subglacial bed topography and ocean bathymetry dataset of Antarctica

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Bed topography and ocean bathymetry are essential characteristics of glaciers and ice sheets. The topography of the bed hidden under the ice is probably the most important boundary conditions of ice sheet models, as it controls the stability of the grounding lines, calving ice front retreat and advance, and other important physical processes that affect ice the discharge of ice into the ocean, and therefore sea level. Ocean bathymetry also determines whether pathways exist for warm, salty subsurface waters to interact with floating ice shelves. Despite significant advances over the past decade in the mapping of subglacial bed topography, such as the development of Bedmap 2, significant sectors of Antarctica remain poorly known, including under major ice streams along coastal Antarctica, which greatly limits the accuracy of sea level rise projections over the 21st century.

We present here a new description of Antarctica's subglacial topography and ocean bathymetry at an unprecedented level of detail, based on different mapping techniques and the latest data collected over the past decades. We combine mass conservation to map fast flowing sectors, gravity inversions to constrain sub-shelf cavities, and anisotropic diffusion in the interior. The method of mass conservation is a new approach that combines sparse ice thickness measurements with high resolution (350 m) satellite derived ice velocity to reconstruct a physically-consistent, detailed bed topography at the same horizontal resolution. The results reveal important features not known previously and shed light on the vulnerability of Antarctica in a warming climate. We find, for example, that most glaciers flowing through the Transantarctic Mountains or along the coast of Victoria Land such as Byrd, David or Mullock glaciers, have a pronounced, wide, topographic barriers a few kilometers upstream of the current grounding line. These ridges, that are not present in previous assessments, act as strong stabilizing points for grounding lines. We find that George V land and the region upstream of Recovery are significantly more prone to the marine ice sheet instability than previously reported. We also show that in some regions, such as Lambert glacier, the radar data suggested a bed topography significantly shallower than what would be consistent with the principle of conservation of mass. This work hence reveals deep valleys that were missing in

previous studies due to these errors in radar data. These features have vast implications for the future of the Antarctic ice sheet and its contribution to global sea level rise.

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Release of the continent-wide dataset GeoMAP v.201907

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Following publication of a South Victoria Land geological map in 2012, GNS Science launched an ambitious project to build a similar high-quality digital geological dataset covering the entire Antarctic continent. With minimal local funding available in NZ, they sought support and enthusiasm internationally through formation of a SCAR Action Group. Five-years later, the first version of GeoMAP (v.201907) will be released at the ISAES XIII meeting, providing a modern geological GIS dataset describing exposed bedrock and surficial geology of Antarctica. Such rapid work was enabled through a clear vision, a tried and tested methodology from mapping New Zealand (QMAP 1993-2014), and a well-defined 'top-down' work-stream.

Construction started from a continent-scale, low density, attribute-poor dataset that has been added to and improved through multiple iterations. It involved capturing existing geological map data, refining its spatial reliability, then improving representation of glacial sequences and geomorphology. Feature classification and description rock and moraine polygons employs international GeoSciML data protocols to provide attribute-rich and queriable data; including bibliographic links to source maps and literature. Around 83,000 polygons are unified for use at 1:250000 scale, but locally have areas with higher spatial precision, founded on a mixed chronostratigraphic- and lithostratigraphic-based classification. There was a specific focus on representation of glacial deposits because of their potential to contain records of ice fluctuations of relevance to climate change.

The project has involved ~18 key collaborators principally from USA, Norway, Italy, UK, Australia, Korea, Russia and New Zealand, but includes contributions from at least 12 nations. Much of the manual work has been completed by 11 student volunteers, who visited NZ on SCAR-supported internships or worked remotely by video-conferencing in return for GIS-training. Peer review of v.201907 will be sought during 2019-2020. One of the hardest tasks has been, and still is, building consistency and capturing the local nuances of different interpretations available. There will undoubtedly be debate as to how well this has been achieved for v.201907. Having been promoted as being 'like a Wikipedia of Antarctic geology' there is full-expectation that GeoMAP will continue to evolve and improve over time. There is potential to provide fresh perspectives, for example, through combined geological legends and interrogation of continent-wide time-space plots. GeoMAP v.201907 provides an underpinning dataset describing the Antarctic geosphere that points directly to published work and will be ideal for continent-wide perspectives and cross-discipline science.

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Change Detection over the major ice shelves of Antarctica using RADARSAT and Sentinel Data

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The Southern Ocean and the area of the Antarctic Ice Sheet are intrinsically linked to global climate and changes in shape and extent of the Antarctic Ice Shelf may be diagnostic indicators of climate change. The recent retreat of ice shelves around the Antarctic coastline has been subject of major concern for the scientific community. The iceberg calving around Antarctica is occurring naturally as a result of increased atmospheric temperature, basal melt, ocean currents, sunami waves and seismic activities. The impacts of climatic variations are more over ice shelves and glacier compared to ice sheets. The melting of the polar ice shelves may not directly affect the mean sea level, but it may affect the dynamics of glaciers, by facilitating higher flow. In the present study, an attempt has been made to monitor the temporal changes in the Antarctic ice margins specially at three hotspot region using Radar Imaging Satellite -1 (RISAT-1) Synthetic Aperture Radar (SAR) data in Coarse Resolution (CRS) mode. Hotspots, where the changes happening at an alarming rate, in Antarctic ice margins have been identified using the 200 m pixel resolution Radarsat Image Mosaic of Antarctica (1997) and RISAT-1 CRS scenes with the help of change detection technique available in ERDAS software. For this we have used delta cue site monitoring and image difference technique. The Site Monitoring process automatically subsets the images, separated in time domain down, to the area of interest and then computes a difference image over the subset. Site Monitoring process also layer stacks the two images into a multi-temporal image. The image difference technique computes the differences between two images, highlighting change that exceeds a user-specified threshold. The After Image (second) is subtracted from the Before Image(first) to provide the image difference and highlight the changes in the image. Three ice shelves were taken for the study such as Pine Island / Thwaites Glacier, Wilkins Ice Shelf and Amery Ice Shelf.

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Mass balance of Antarctic ice sheet based on CryoSat-2 from 2011-2018

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Antarctic ice sheet is the main driving factor of global sea level rise, so its mass balance monitoring is particularly important. Elevation change measurement is an important means to monitor the mass balance of Antarctic ice sheet. Using ESA Cryosat-2 radar altimeter data and taking each month as the basic unit, a new model fitting method was established to estimate the elevation changes of the whole Antarctic ice sheet and 27 basins. The surface density model was further used to transform the elevation changes into mass changes, and the results were validated with GRACE gravity satellite data, ERA-Interim reanalysis data and regional climate model (RACMO2) data. The results show that the mass changes of Antarctic continent, West Antarctica, East Antarctica and Antarctic Peninsula in 2011-2018 are -161.9±32.6, -136.7±27.4, -3.1±36.3, -23.5±18.2 Gt/yr, respectively. Among them, the mass change in the West Antarctica is 35% higher than that in 2005-2010 of the previous study. Compared with the mass changes calculated by other three mothods, it is found that the mass changes of gravity satellite estimates are the largest, while the mass changes of ERA-Interim reanalysis data estimates are the smallest.

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High-resolution remote sensing techniques for monitoring penguin colonies in the Ross Sea, Antarctica

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Penguins have been recognized as one of the indicators of environmental changes (e.g. varying sea ice conditions) in Antarctica; therefore, monitoring penguin colonies is important for investigating the effects from the environmental changes. In this study, we applied high-resolution remote sensing techniques, i.e., high-resolution satellite imageries and unmanned aerial vehicle (UAV) images, for efficient monitoring Adélie penguin (Pygoscelis adeliae) colonies in the Ross Sea, Antarctica. It is reported that more than 30% of Adélie penguin population breed in the coastal areas in the Ross Sea. To precisely delineate the colonies, high-resolution imageries from multiple multispectral satellite sensors, e.g., WorldView-2, WorldView-3, Korea Multi-Purpose Satellite-2 (KOMPSAT-2), KOMPSAT-3, etc., were collected in the study areas. Ground truth data for spectral analysis of the colonies were collected using hyperspectral imaging camera during field investigation. Based on the collected field spectra, penguin colony potential index was proposed with a consideration of low solar angle condition in Antarctica, and then applied to the high-resolution satellite imageries. From the results of the satellite imagery based penguin colony mapping, the locations, areas and distribution of the colonies were identified. For more detailed investigation on the colonies, very high-resolution UAV images were acquired in Cape Hallett, Antarctica. The UAV image acquisition has merits of shorter operation duration than field investigation by researcher, decreased disturbance to colonies and penguins and providing vertical viewing geometry preventing overlapping between penguins during counting. The UAV images were mosaicked and then used for counting individual penguins. The counting individual penguins was conducted using Google's tensorflow object detection application programming interface (API). These high-resolution remote sensing techniques can be applicable to the penguin colonies in other regions in Antarctica or other species of penguins, e.g., emperor penguin.

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Session23: Advanced Technologies for Research and Operations in Polar Regions

Hydraulic fracturing in fissured ice borehole wall: theory and tests

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In the deep ice core drilling process, there are randomly distributed micro cracks or fractures in the ice body due to the influence of various geological factors. This fissured borehole wall will cause hydraulic fractures under the action of imbalance between drilling fluid column pressure and ice pressure, which lead to the borehole wall instability. This paper investigated the hydraulic fracturing of fissured ice borehole wall through theoretical and experimental research methods. Theoretical research based on fracture mechanics shows that the existence of fissured structure in the borehole wall will cause the decrease of stability. Moreover, the fracture toughness, ice friction coefficient and the fracture state in the ice played important roles in determining the borehole critical failure pressure, and the safe pressure window of drilling fluid in the fissured borehole reduced by 55% compared to the unbroken one. The result of experimental research based on self-designed true triaxial hydraulic fracturing test system indicates that the crack propagation is affected by the stress distribution in three directions and the weak cementing surface in layered freezing for the fissured structure. However, for the borehole wall caused by cold and heat effect, the cracks initiation and expansion forms are relatively uniform and the expansion pressure is approximately equal to the minimum horizontal principal stress. In conclusion, to ensure the stability of the borehole wall, the drilling fluid pressure should keep as low as that overburden pressure and special attention about the change of the liquid level when drilling through the fissured ice layer.

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Session23: Advanced Technologies for Research and Operations in Polar Regions

A New Smart System of Rapid Continuous Coring Drilling with Air Reverse Circulation in Antarctica

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Rapid ice coring is one of the most important means of the polar scientific research, which is of great significance for research of earth system science. However, rapid ice core drilling technology and equipment is a bottleneck of the polar scientific research under the polar extremely harsh and cruel work condition. The conventional polar ice core drilling equipment work effectively in a short time (effective working time is only about 20 days to estivate at Kunlun Station at Dome A, East Antarctica, and effective working time is less than two months to pass the summer at Zhongshan Station) to drill in the ice at an average drilling speed of 20~30 m per day, then a month maximum drilling depth is about 500 m of ice. Through making a breakthrough in the key technology, a set of ice drilling equipment is researched and developed for rapid continuous coring drilling with air reverse circulation in the polar ice to a depth of 500-800 m in Antarctica at drilling speed of 30-50 m/h within 3-5 days, including a set of drill pipe automatic quick connect system, ice core automatic discharge and collect system, along with high integration, lightweight, automation and intelligence. This equipment mainly includes rapid and continuous ice-coring drilling tools with full-hole air reverse circulation, the fast drilling system on the surface of the ground, automation system of quickly adding drilling pipe and ice core collection, transmission and emission system, etc.

A169

Session23: Advanced Technologies for Research and Operations in Polar Regions

Autonomous Instrument Network for Coordinated Observations at Remote Antarctic Locations

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We report on the development and operation of an automated ground-based instrument network extensively distributed at remote locations in Antarctica. The network elements are designed to host leading-edge earth and space science instrumentation, and collect data automatically in this unforgiving environment with minimum service visits required. The power/telemetry platforms utilize solar panels, wind turbines, and batteries, as well as two-way satellite communication for data acquisition and system control. The network was originally developed in the 1980's as part of the United States National Science Foundation (NSF)-supported Automatic Geophysical Observatory (AGO) program and has been operationally successful across the Antarctic ice shelf. Now the program is managed, maintained, and upgraded by the Polar Engineering Development Center (PEDC) housed at the New Jersey Institute of Technology (NJIT). The PEDC consists of a highly skilled group of collegiate professors, research scientists, electrical and mechanical engineers, and technicians that have decades of experience in instrument and hardware design for deployment in high latitude/polar regions. Using its long and highly successful experience, the PEDC is reaching out to serve the broader scientific communities conducting research in Antarctic environments by providing support in the areas of (a) sustainable "green" power generation in the 10 to 200-W range, (b) power conditioning and control, (c) robust engineering for polar climates, (d) data acquisition techniques, units, and transmission services, and (e) general polar field support. The PEDC also encourages researchers across all disciplines to consider the opportunities that the network can provide for instrument deployment and data acquisition at these remote locations. An upgraded version of the instrument platform is now being developed for deployment in another deep field location in Antarctica as part of the Antarctic Korean Route Expedition project run by the Korea Polar Research Institute (KOPRI). In this presentation, we review the PEDC, its current capabilities, the deep field network, and provide technical information for interested parties.

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Session23: Advanced Technologies for Research and Operations in Polar Regions

Development of OPV (Optional Piloted Vehicle) for Polar Research

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OPV (Optional Piloted Vehicle) is one of the UAV (unmanned aerial vehicle) development techniques and methods that can provide economical and efficient unmanned systems. Conventional manned aircraft are evaluated through numerous flight operations in a variety of environments, including extreme cold, and can provide a reliable aircraft platform, engine and subsystem for operation. Developing UAVs using proven manned aircraft can therefore reduce development time and risk of accidents. In addition, since manned aircraft generally have a large payload and can operate for a longer time than UAVs, it is advantageous to explore a wide area with a variety of mission equipment. This paper describes the basic specifications of OPV development using CTLS aircraft. This includes plans to install basic devices for unmanned operation (flight control systems, control surface actuators, communication equipment, ground control equipment), and various mission equipment such as cameras, RADAR, and some sensors for polar research. CTLS is a two-seater aircraft designed specifically for the Light Sport category. By replacing the Rotax 912 ULS engine with the Rotax 912 IS engine to convert CTLS airplane to OPV, fuel efficiency can be improved more than 32%. It is also designed to be unmanned by control surface actuator, throttle and brake actuator. An alternator is added to secure the power supply for the mounted systems (unmanned system, sensor, etc.) and can be supplemented by the required power. In addition, a vehicle type ground control device capable of controlling the OPV from the ground is developed. Mission equipment can be equipped with various sensors through design changes. UWB (Ultra-Wide Band) radar antenna arrays will be installed on aircraft wings to observe the subglacial topography of Antarctica. The airplane is also designed for variable installation of Lidar, hyperspectral sensors, and SAR (Synthetic-Aperture Radar) for various polar researches. The communication device is comprised of an on-board communication device and a ground communication device, and is designed to control and monitor the OPV within a 50 km operation range via two line-of-sight data links. In addition, the satellite data link can be added to control and monitor the aircraft even at a distance of 300 km or more. The ground control system has a basic function of aircraft control, mission control and monitoring functions. It is reinforced with a Cockpit Display Traffic information (CDTI) that can display surrounding conditions and weather conditions to support safe operation.

By constructing a HILS (Hardware-in-the-Loop Simulation), it is possible to develop a more stable system by checking the operation mode, training the operators, improving the reliability of flight and unmanned platform and verifying tests. The HILS system can be used to carry out tests for each equipment and system and identify systems to be added or changed. ADS-B based unmanned aerial collision avoidance system is under development and further automatic takeoff and landing system and satellite data link will be developed in the near future. These functions will compensate for the inconvenience of operating distance and operability of vehicle. The OPV will be used for Antarctic exploration with various mission equipment and will be used for Antarctic exploration, beginning with test flights in Antarctica in 2022.

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Session23: Advanced Technologies for Research and Operations in Polar Regions

Ultra-Wideband Multiple Input and Multiple Output Radar for Airborne Ice Sounding and Imaging

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We are developing an ultra-wideband (UWB) multiple-input and multiple-output (MIMO) radar for airborne measurements of ice in Antarctica. We are designing the radar to operate over the frequency range of 170-450 MHz with a peak transmit power of 500 W and a pulse repetition frequency (PRF) of 10 kHz. The radar will operate with 1-μs and 10-μs long pulses on alternate transmission intervals. The transmission of a short pulse is followed by nine long pulses, and process is repeated until a preset number of pulses are coherently integrated. – This is to obtain the high sensitivity required to sound thicker ice with the higher power-aperture product of the long pulses and a higher coherent gain by transmitting more long than short pulses. The short (1-us) pulse sounds and images shallow ice with thicknesses less than 1 km. The long (10-us) pulse sounds and images ice thicker than 1 km, up to a maximum thickness of about 5 km. UWB operation implies that the second- and third-order harmonics generated by the power amplifier fall within the band of interest. Our approach suppresses the even-order harmonics by using a push-pull configuration. We also suppress the odd-order harmonics by arranging two push-pull amplifiers in a balanced topology using quadrature hybrids.

We will integrate the radar into a light-sport-aircraft (LSA) with an 8-element array consisting of four pylon-mounted antenna elements under each wing, with the carbon fiber composite lower-wing surface acting as a reflector. We will optimize the internal and external radar hardware and flight properties within the structural, volume, weight, access, and power budget constraints inherent in the small LSA platform. The pylons are cantilevered composite N-struts attached to a low-drag fiberglass pod containing the individual antenna elements and mount into the carbon fiber wing ribs aft of the spar. We will optimize the spacing between these elements to synthesize a 7-8 element cross-track virtual array by transmitting I and Q signals simultaneously from two farther elements of the mounted antenna array under one of the wings. To obtain fine resolution, we will employ synthetic aperture radar (SAR) processing in the along-track direction and array processing in the cross-track direction using this virtual array. The data collected with this radar system can be processed to produce traditional nadir sounding mode radar echograms and 3-D images over a 1-2 km swath. The ice thickness, scattering characteristics of the ice-bed interface, and aircraft altitude over the ice surface will determine the swath width. This presentation will outline the design and simulation results for this radar and show sample results from other similar systems over the Antarctic and Greenland ice sheets.

A306

Session23: Advanced Technologies for Research and Operations in Polar Regions

Ultra-wideband Microwave Radars for Airborne Mapping of Near-Surface Internal Layers in Polar Firn and Ice

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Airborne ultra-wideband (UWB) microwave radars' potential for fine-resolution measurements of snow over ice and land has been demonstrated [1-4]. Designed to operate as frequency modulated continuous wave (FMCW) systems, the early versions of these radars generated the transmitter chirp by using UWB voltage-controlled oscillators (VCO) in a phased-locked loop (PLL) with a low-frequency digital chirp as a reference. The performance of these radars was degraded by chirp signal non-linearities particularly for airborne measurements. To overcome this limitation, the later versions generated the UWB chirp by frequency multiplication of a low-frequency baseband digital chirp over 2.5-3.5 GHz. Each stage of frequency multiplication by a factor of 2 results in 6-dB sidelobe degradation, which limits the radar performance when mapping closely spaced layers. The range sidelobes of earlier radars had to be reduced with extensive post-processing using calibration targets. This made it difficult to evaluate the quality of data being collected in the field. To further improve radars' performance with minimal post-processing and improve dynamic range, we are developing a radar that operates over 2-19 GHz with six 3-GHz sub-band digital chirps concatenated to obtain a 17-GHz bandwidth chirp. Our new chirp system generates a 10-us long 2-5 GHz digital chirp. The baseband (2-5 GHz) chirp generator and associated amplifiers and filters are optimized to get close to the ideal impulse response function of an FM-CW radar. This chirp is upconverted sequentially into five sub-bands of 4.8-7.8 GHz, 7.6-10.6 GHz, 10.4-13.4 GHz, 13.2-16.2 GHz, and 16-19 GHz and then combined to obtain 60-us long 2-19 GHz chirp. The upconverted chirps are overlapped by 200 MHz for phase matching of the end of the previous sub-band and the next sub-band chirp. This approach will provide a nearly ideal impulse response function to resolve closely spaced layers with a range resolution of about 1.5 cm. The purpose of this paper is to discuss improvements made to our UWB radars using the sub-band chirps, to present new results over different targets, including simulated targets, and discuss future plans.

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Session23: Advanced Technologies for Research and Operations in Polar Regions

Absolute Gravity Measurements in 2017/2018 and 2018/2019 Season in Dronning Maud Land and Enderby Land, East Antarctica

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The effects of Glacial Isostatic Adjustment (GIA) is one of the largest uncertainties to reveal the mass changes of Antarctic ice sheet using satellite gravity data, or to reveal ice sheet height changes by satellite altimetry and other geodetic techniques as well.
As a part of a five year research project "Giant reservoirs of heat/water/material: Global environmental changes driven by Southern Ocean and Antarctic Ice Sheet", which is funded by JSPS (Japan Society for the Promotion of Science) and has launched in 2017, we are involved in the studies related to "Interaction of the solid Earth and the Antarctic Ice Sheet".
As an activity of the project, we have conducted Absolute Gravity (AG) measurements and GNSS measurements at Japanese Antarctic station, Syowa and 6 outcrop rock areas in the framework of the 59th Japanese Antarctic Research Expedition (JARE59) in 2017/2018 season. And in 2018/2019 season, we have conducted the same measurements at Troll, Norwegian station, and Maitri, Indian station under the supports of the Norwegian Antarctic Research Expedition and the Indian Antarctic Expedition, respectively.
We employed an indoor type absolute gravimeter FG-5 #210 for the AG measurements at Syowa, Troll and Maitri, and employed outdoor type absolute gravimeter A10 #017 for the measurements in the field.
In the presentation, we will report the details of the field operation and the obtained results with their measurement errors as well as expected gravity changes from GIA models.
This study was partially supported by JSPS KAKENHI Grant No. 17H06321.

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Session24: Earth science informing environmental management and policy

Use of 'boosting', 'bagging', ensembles (Machine Learning) and telecoupling for data mining and predictions of open access biodiversity: an example on charismatic penguins

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Modern science provides us with many opportunities, but they remain widely underused and not implemented in good conservation policy. Here I provide a review of work done for Antarctica employing 'boosting (TreeNet) and bagging (randomForest)' algorithms combined in ensemble models to achieve cutting-edge data mining and predictions. I will further show the wider and equally complex use of, and combination with, telecoupling analysis, where global aspects and data (sending, receiving, spill-over effects) are better taken into account for a progressive and more holistic understanding of patterns and processes like the ones found in Antarctica. I will use penguins as an example, and show open access approaches to data and code for achieving study aims of data cleaning, data summaries, outlier analysis, niche predictions and climate change forecasts. Due to the overwhelming progress and high performance of such methods I argue those analysis platforms are becoming a standard and best professional practice for dealing with Natural Resources anywhere.

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Session24: Earth science informing environmental management and policy

Involving Antarctic communities in the management of geoheritage: a case study in

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The "Base Esperanza" is a permanent Argentine station located in Hope Bay, in the northern Antarctic Peninsula. Together with "Villa Las Estrellas" station (Chile), Esperanza is one of the two citizen settlements in Antarctica. Every year, several families that live at the station take their children to the local school. The area is visited by tourists each summer. Few kilometers from the station, there is a paleontological site known as Monte Flora. This locality includes the Monte Flora Formation, a Jurassic continental clastic sequence of which fossil floristic diversity is unique in Antarctica and other localities of the Southern Hemisphere. The fossils plants testify the presence of large forests of conifers and ferns, which developed approximately 180 million years ago in this sector of the current Antarctic Peninsula. This geosite has been protected since 2002 in the framework of the Antarctic Specially Protected Area (ASPA) No. 148. Despite the benefits of being protected, the restrictive nature of the ASPA make it difficult for the Antarctic community (i.e. station staff and families, tourists, scientists) to appreciate the value of this site (mainly scientific, educational and touristic). In this context, the Instituto Antártico Argentino (IAA) initiated a comprehensive action plan of environmental education and enhancement of the geological heritage of Monte Flora, aimed to achieve an internalization of the concept of geoheritage in the community through the awareness and understanding of their environment and its conservation. Regarding environmental education, systematic educational activities with a geo-conservationist approach were proposed for the staff, families and schoolchildren of the Esperanza station, as well as the incorporation of geological topics in the training of local tour guides (also staff members). In order to highlight geosite´s value, we have proposed to create visual support signs and to assemble a paleontological and geological collection, which is currently exhibited at the station's museum. This collection belongs to the "Antarctic Repository of the Paleontological and Geological Collections" of the Instituto Antártico Argentino, and represents the first collection of the IAA in the Antarctic Continent. The open access collection is managed through a protocol that provides guidance on procedures for handling fossil samples. In addition, the IAA annually selects a collection manager (curator) to ensure fossils proper care and conservation. During the 2019 summer Antarctic campaign, the staff of Esperanza was lectured about the importance of Monte Flora, and the community inaugurated and visited the collection. Special emphasis was placed on maximizing staff participation in order to promote community ownership of the project. In this sense, part of the staff participated as assistants during field works, made special furniture to keep and exhibit the fossil collection, organized its inauguration at the museum and participated in the design of information signs. Currently, station teachers, the collection manager and local tour guides, have an active role in the project. We expect that this case study can help to provide new ideas for integration of the Antarctic communities and geoheritage management in the Antarctic continent.

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Session24: Earth science informing environmental management and policy

Recent advances on Antarctic geoconservation

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The attention to the identification and protection of the geological heritage, as well as the establishment of concepts and methodologies for these purposes, has increased in the last three decades in many parts of the world. In general, developments have been at a national scale, but also with interesting international initiatives, like those promoted by the UNESCO World Heritage Cultural and Natural Convention, the International Union of Geological Sciences (IUGS) and the European Association for the Conservation of Geological Heritage (ProGEO). In the last few years, the interest about the conservation of Antarctic geological heritage has increased within the Antarctic community and the Antarctic Treaty System. Motivated mainly by the effects of geological oversampling, the Committee on Environmental Protection (CEP) asked SCAR to provide advice about ways to advance the protection of Antarctic geological heritage. For this purpose, SCAR established in 2014 an Action Group on Geological Heritage and Geoconservation to consider the systematic protection of geological values, open to the participation of the interested members of the Earth sciences community. The Action Group considered it appropriate to apply the Global Geosites Project methodology, promoted by the IUGS to develop a global inventory of the geological heritage of the Earth, using a systematic methodology based on the selection of Geological Frameworks of international relevance and the Geosites representing them. However, the identification and management of Antarctic geological heritage needs be adapted to the special circumstances of the Antarctic territory, which are different from other parts of the world, i.e.: the multinational administration and management, a general protection regime established by the Protocol on Environmental Protection to the Antarctic Treaty, the prohibition of commercial mineral extraction, the need to conduct environmental impact assessments, regulations for sample collection, and the existence of a protected areas system (Annex V on Area Protection and Management). The designation of Antarctic Specially Protected Areas (ASPA) includes among possible elements for designation of an ASPA: "outstanding geological, glaciological or geomorphological features", although few of the current ASPAs have been declared for geological reasons. The establishment of new infrastructures, increase of visitors, and extension of scientific activities may in some cases result in irreversible damage to Antarctic geological values and an increase in oversampling. These potential threats to geological heritage need to be reduced, as well as to promote the exhaustive use of existing collections. This presentation discusses: i) the general guidelines for identification and protection of the geological heritage, ii) the steps followed for their adaptation and application to the particular case of the Antarctic region, iii) the updated state of the identification of the Antarctic geological heritage, the SCAR advice to the Committee on Environmental Protection and the outcomes of discussions at CEP about this topic, and iv) the future perspectives and steps to identify Antarctic Geosites. The possible adaptation of the initial Antarctic geological frameworks and the identification of Antarctic Geosites imply challenges requiring a good knowledge of Antarctic geology, as well as of the principles and methodologies related to the identification and assessment of geological heritage. The advances made and the future developments on identifying and advising about the conservation of Antarctic geological heritage have been, and should continue being, a joint venture of the international Antarctic Earth sciences community under the SCAR umbrella.

A025

Session26: General Topics

Characteristic multi-sphere interaction in the coastal and marine environment inferred from infrasound observation at Terra Nova Bay, Antarctica

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Characteristic features of infrasound waves observed in the Antarctic reveal physical interaction involving surface environments around the continent and Southern Ocean. In December 2015, an infrasound array (100 m spacing) by three sensors (Chaparral Physics Model 25, with a detectable frequency range of 0.1-200 Hz), together with a broadband barometer (Digiquartz Nano-Resolution Model 6000-16B Barometer, with a detectable frequency range of 0-22 Hz) were installed at Jang Bogo Staion, Terra Nova Bay, Antarctica by the Korea Arctic and Antarctic Research Program (KAARP). The data for two years recorded by the broadband barometer contain characteristic signals originated by surrounding environment, including local noises such as katabatic winds. Clear oceanic signals (microbaroms) are continuously recorded as the background noises with predominant frequency around 0.2 s. Variations in their frequency context and amplitude strength in Power Spectral Density had been affected by an evolution of sea-ice surrounding the Terra Nova Bay. Microbaroms measurement is a useful tool for characterizing ocean wave climate, complementing other oceanographic, cryospheric and geophysical data in the Antarctic. Continuous infrasound observations in Terra Nova Bay attain a new proxy for monitoring environmental changes such as the global warming, involving cryosphere dynamics, as well as the volcanic eruptions in Northern Victoria Land, Antarctica. In this presentation, result from Terra Nova Bay is compared with those obtained from the Lutzow-Holm Bay, East Antarcitca, which have been conducted by the Japanese Antarctic Research Expedition (JARE).

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Session26: General Topics

Stopping the Flood: Continued Progress in Targeted Glacial Geoengineering

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Rapid sea level rise due to an ice sheet collapse has the potential to be extremely damaging to coastal communities and infrastructure, and conventional coastal protection techniques (dykes, levees, etc) can be quite expensive. We have proposed that it might be cost-effective for society to employ targeted geoengineering efforts at critical marine ice streams and outlet glaciers to slow the rate of sea level rise. The most important forcings acting on a marine ice sheet are submarine melt near the grounding line and physical buttressing of the floating shelf. Our proposed design entailed building large earthen structures underwater: either a continuous dam which could both block warm water and provide buttressing, or isolated pinning points which could only provide buttressing. Separately, other researchers have found that a thin metal barrier in the water column would be more cost-effective for blocking warm water than an earthen dam, even if it is incapable of providing physical buttressing. Here, we combine the two designs to consider isolated earthen pinning points for providing buttressing with a thin barrier between them for blocking warm water. This design is able to achieve a higher success probability than either one individually, since it addresses both major forcings on marine ice sheet dynamics in a cost-effective manner. These results demonstrate that iterated improvements can increase the effectiveness of targeted geoengineering designs and improve the chances that society will have effective options if we are ever faced with a rapidly collapsing ice sheet in the future.

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Session26: General Topics

Pollution assessment in the Bransfield Strait in the Antarctic

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One of the problems that has been occurring worldwide is the pollution of the environment, such as soil, air and water. In this sense, anthropogenic activities introduce these elements into the environment and can reach places as isolated as the Antarctic. Heavy metals are chemical elements that have an environmental interest due to their repercussions in different environmental areas; the high levels of these metals in the benthic sediments of the zones allow us to determine the level of toxicity and their potential involvement in the trophic chain.
In this sense, evaluating the pollution of water and sediments from Bransfield Strait in the Antarctic is of great interest. The experimental part will be developed in two stages: fieldwork and cabinet. In the fieldwork, the evaluation will be carried out by monitoring in situ physicochemical parameters such as temperature, pH, DO, BDO, turbidity, conductivity, anions and heavy metals. In addition, water and sediments samples will be taken to carry out a more exhaustive study of biological parameters if possible.
Continuous pressure registers (depth, temperature, salinity and oxygen) in the water column up to the depth 1600mm, using a CTD Sea Bird Electronics (SBE) Model 9 Plus, in sixteen oceanographic stations were carried out. Eight stations located on Mount Orca (62 26.05 S; 058 30.92 W) and eight parallel points (between 62 33.51 S; 058 11.84 W and 62 45.32 S; 058 50.49 W) all located in the Bransfield of Strait.
Sixteen Rosette launches were made for the collection of 63 water samples, at standard depths according to the depth of the sampling site (10, 250, 600 and 50m minus the seabed) for determination of dissolved oxygen, salinity, pH, Nutrients (phosphates, silicates, nitrates and nitrites). Salinity was determined by the induction method, using the Portasal Guildline model 8410A.
The surface salinity of the sea presented values between 33.3 to 34.6 ups. The highest concentrations were located in greater depths to the 1300nm the interior of the Strait Bransfield; For its part, the lower concentrations of salts were located in areas adjacent to Nelson Island. Sea surface temperature (SST) fluctuated between-1.23 ° to + 2.26 °C, averaging at 0.6 º C for the entire evaluated area. The thermal distribution was characterized by presenting a typical behavior of this area, ie with the highest temperatures in the area adjacent to the South Shetland Islands and the lowest in areas near the Antarctic Peninsula.
Dissolved oxygen (DO) presented values between 5.89 and 9.91 mL/L, with an average of 7.98mL/L, with a relatively homogeneous surface distribution with certain nuclei of high values, such as the one located inside the Bransfield Strait even at deep levels greater than 1500m.
The Potential of Hydronium (pH) was measured in situ, which presented values between 7.62 and 8.34; With an average of 8.10, low values were presented below 1200 and 250 nm in front of Nelson Island and in the area inside the Bransfield Strait respectively.
With the obtained results, it will be possible to elaborate a table of valuation of the measured parameters and their respective concentrations. This will allow building a matrix of pollution values in the sampling area.

A189

Session26: General Topics

Iceberg-induced tsunami events observed by tide gauge at the Zhongshan Station, Antarctica

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Inside the tide gauge observations at the Antarctic Zhongshan Station, there are some high frequency abnormal signals related to the iceberg activities. This study compared the camera recorded iceberg rollover events with the high frequency sea level anomalies observed by tide gauge station, which proved that the iceberg activities were the source of the local tsunamis. We picked out all the sea level anomalies from tide gauge records between 2017 and 2019, and analyzed the features of iceberg-induced tsunami, including the duration, amplitude, seasonal distribution and yearly changes. This kind of tsunami will definitely happen again at Zhongshan Station, and our study provided helpful literature for preventing potential damages in the future.

A329

Session26: General Topics

Spectral characteristics of the Antarctic vegetation: A case study of the Barton Peninsula

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Spectroscopy is the study of light as a function of wavelength that has been emitted, reflected or scattered from a target. As photons enter a target, some are reflected from the target, some pass through the target, and some are absorbed. All natural surfaces including solid, liquid, or gas have their own physical characteristics of reflection, refraction and absorption. Monitoring of vegetation changes in the Antarctic Peninsula plays an important role in global climate change. Changes in vegetation can be obtained from optical remote sensing sensors, also known as imaging spectroscopy. Therefore, obtaining spectral characteristics of various vegetation species in the Antarctic Peninsula is important to understand remote sensing images quantitatively. In this study, we obtain spectral reflectance of 17 vegetation species which can be easily found in the Barton Peninsula, and analyze spectral discriminant between species using spectral statistics. Synthetic hyperspectral remote sensing images that generated based on the knowledge on vegetation distributions in the study area are exploited to further analyze spectral characteristics.

A343

Session26: General Topics

THE DEGLACIATION PROCESS OF ICE-FREE ENVIRONMENTS IN THE SOUTH SHETLAND ISLANDS

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Permafrost is now widespread in most ice-free environments in the Maritime Antarctica. In the NW tip of the Antarctic Peninsula, the occurrence of permafrost is determined by the elevation, glacier-temperature regime as well as by the time of deglaciation. In the South Shetland Islands (SSI), the retreat of polythermal glaciers since the Last Glacial Maximum (LGM) has exposed the land surface and favoured the existence of permafrost. However, although inferring the calendar of deglaciation is crucial to better understand the geomorphological and climatic meaning of present-day permafrost conditions in this archipelago, our knowledge is still limited. With the purpose of providing insights into the deglaciation process, we have applied surface exposure dating methods using the in situ cosmogenic nuclide 36Cl to deglaciated polished surfaces on basaltic rocks. Up to 26 samples were collected in January 2017 from three old volcanic plugs that constituted nunataks during the deglaciation (Chester, Cerro Negro and Clark). These features are distributed across the central plateau of Byers Peninsula, the largest ice-free area (60 km2) in the SSI. Here, our understanding of the spatio-temporal pattern of deglaciation was only based on a few radiocarbon dates from lacustrine sediments and geomorphic evidence. Preliminary results show that glacial thinning already started during the LGM, with the summit surfaces of nunataks becoming ice-free between 26 and 19 ka. A first phase pulse of rapid deglaciation occurred until 17-16 ka followed by a relative glacial stability until 12-11 ka. Subsequently, there was another stage of massive glacier retreat during the Early Holocene that exposed the central plateau by 8-5-7.5 ka. The rapid shrinking promoted the development of currently inactive permafrost-related landforms, such as block streams in Cerro Negro slopes, suggesting much colder climate conditions than present. Although the eastern slope of nunatak Clark is still surrounded by the Rotch dome glacier, the deglaciation followed a similar temporal pattern, with its western fringe being deglaciated by 7.5 ka. These new preliminary results confirm that the first deglaciated environments in the northern Antarctic Peninsula appeared much earlier than known to date, which has major implications for understanding permafrost distribution and vegetation colonization in Antarctica. These (paleo)nunataks must have acted as biodiversity hotspots during the Late Pleistocene and throughout the Holocene. This research is being complemented with ongoing studies from other enclaves of the SSI to infer the calendar of glacial oscillations since the LGM.

A419

Session26: General Topics

Presence of heavy metals in McKellar inlet, Admiralty Bay, King George Island, Antarctica

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In the ANTAR XXV expedition, during the southern Antarctic summer (2017-2018), a sampling campaign was developed in McKellar Inlet. The main objective is to evaluate the presence of heavy metals and the possibility of human contamination in these areas, due to the proximity of the Peruvian Station.

Several studies in sediments in Admiralty Bay and around the permanent scientific research stations shows high concentrations of Cu and Zn, associated with the natural mineralized rocks presents around Keller Peninsula (Machado et al, 2001; Trevizani et al, 2016). But we do not have reference values in the McKellar Inlet.

Around McKellar Inlet, the geology shows andesitic and dacitic volcanic successions cut by dioritic intrusions. A small alteration halo was observed at the west near to Domeyko Glacier, and an extended alteration zone is present in Keller Peninsula.

The sampling campaign was considered a sampling mesh of 23 sediment samples, to evaluate the presence of As, Co, Cr, Cd, Cu, Mn, Mo, Ni, Pb and Zn. The samples were taken with a dredger of 0.25 m on board a boat. Considering mainly the zones of sedimentary accumulation. The dredging stations vary from 20 to 50 meters, only 3 samples are deep (100 -150 meters).

The ranges in the contents of heavy metals are uniform and present slight variations As (12-28 ppm), Co (19-24 ppm), Cr (30-44 ppm), Cu (95-126 ppm), Mn (600- 1000 ppm), Mo (2-3 ppm), Ni (11-18 ppm), Pb (5-9 ppm) and Zn (71-97 ppm), no Cd values was detected

Session26: General Topics

Episodic enhancement of sea ice survivability in the glacial Southern Ocean driven by Antarctic warming

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The Southern Ocean (SO) played an important role in the evolution of the global climate system. The sea-ice coverage area exhibits large seasonal and internannual variations, which in turn strongly impacts Southern Hemisphere Climate through multiple processes including modulation of the energy budget, affecting atmospheric circulation and gas concentration, modifying the hydrological cycle, and controlling biological productivity. Pioneer work in the SO with siliceous microfossil records suggests that winter sea ice coverage significantly expanded equatorward during the Last Glacial Maximum (LGM). However, millennial-scale sea ice coverage and its impacts remain poorly understood. Here we report high-resolution ice rafted debris (IRD) and diatom assemblage records that covary, suggesting the IRD is sourced from sea ice (S-IRD). This further reveals rapidly changing sea ice distribution in the Indian sector of the SO over the last 43,500 years. We document ten events of increased sea-ice coverage related with the Weddell Gyre (WG) between 42,000 and 16,000 years ago, each of which occurred during Antarctic Isotope maximum (AIM) warming events. Sea ice expansion events might be caused by a combination of two factors, movement of the high sea-ice production area in the northern Weddell Sea and enhancement of sea-ice survivability in the Subantarctic waters due to a surface water freshening caused by Antarctic ice sheet melting during the warming.

A481

The Cytological, Microbiological and Ophthalmic Evaluation of Ocular Surface Samples Taken from Penguin Species of the Antarctic Peninsula : Preliminary evaluation of the results belong to ten eye swabs

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The study aims to assess the efficiency and usability of ocular surface cytology,in terms of cellular and microbiological diagnosis, in penguins belonging to the Pygoscelis genus, and to establish reference values by means of ophthalmic tests. The ophthalmic and ocular surface sampling was performed in the South Shetland Islands and in the northern part of the Antarctic Peninsula. Adult (n = 87) and chick (n = 13) penguins were sampled from all island.

The first part of the study involves the collection of ocular surface cell samples by exfoliative cytology from penguin species of the genus Pygoscelis, which inhabit the islands of the Antarctic peninsula, namely, the Adelie penguin (*P. adeliae*), Chinstrap penguin (*P. antarcticus*) and Gentoo penguin (*P. papua*)... For examination of cytological samples, impression and brush cytology techniques were used..Cell specimens collected by brush cytology were used for the evaluation of cell morphology and the presence of bacteria, fungi after undergoing cytospin centrifugation. Cytological changes were evaluated under light microscopy according to Nelson's grading system. Impression cytology was used as a simple method for the sampling and counting of conjunctival goblet cells. Due to the adhesion capability of the sampling device, impression cytology were used to collection of the most superficially located cells on the ocular surface. Corneoconjunctival surface epithelial cells and sporadic inflammatory cell infiltrations were observed. High rates of goblet cells were noted in some of the preparations. Microscopic examination of preparations revealed superficial, intermediate and basal epithelial cells organized in layers. Degenerate epithelial cells, fibrine, neutrophil leukocyte, bacteria and fungi ,cellular debris and mucus were detected on eyes .

The second part of the study objective of this study is to investigate the bacterial ocular flora of healthy penguins in Antarctica. The bacterial flora of the eyes of penguins found in Lion Ramp island was investigated. For this purpose ten eye swap samples were analysed. The samples were directly inoculated onto tryptic soy agar containing 5% sheep blood. The inoculated petri dishes were incubated at 37 ^{0}C under aerobic and microaerobic conditions for 24-48 hours. Furthermore, the swabs were also placed into brain-heart infusion broth and incubated under aerobic and microaerobic conditions for 24 h. The cultures grown were inoculated onto tryptic soy agar containing 5% sheep blood and the inoculated petri dishes were further incubated at same conditions mentioned above. Then the colonies were examined macroscopically (size, colour, odour, haemolysis, etc.) and microscopically. Each different colonies were subcultured on sheep blood agar to obtain pure cultures. Phenotypic (including Gram staining, catalase, oxidase, motility and carbohydrate fermentation tests) and molecular test (16S rRNA sequence analysis) were used for the identification of the isolates recovered.

As a result, a total of 18 isolates were obtained from 6 (3, 2, 5, 1 and 4 isolates from each sample respectively) of 10 samples collected. Isolates were identified as Psychrobacter sp. (9 isolates from 5 samples), Psychrobacter sanguinis (2 isolates from 2 sample), Corynebacterium sp. (2 isolates from 2

sample), Corynebacterium sphenisci (1 isolate from 1 sample), Psychrobacter phenylpyruvicus (1 isolate from 1 sample), Brachybacterium sp. (1 isolate from 1 sample), Moraxella osloensis (1 isolate from 1 sample) and Pseudoarthrobacter oxydans (1 isolate from 1 sample).
The third part of the study tear production and intraocular pressures (IOPs) were determined in total 100 penguins from the Yelchoo, Base General Bernardo O'Higgins, Harmony point Lion ramp,Ardley protected area. Tear production was measured by Schirmer tear test, and IOP was measured with a TonoVet rebound tonometer. This is the first study, to our knowledge, investigating tear production and IOP in Pygoscelis penguins and establishes valuable reference intervals for this species.