ESF EARTHTIME-EU Scientific Meeting

"The Early-Middle Pleistocene transition: Significance of the Jaramillo Subchron in the sedimentary record"

Burgos, 24-27 September 2013

DAN-16 Jaramillo locality (Gona area, Ethiopia)

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Meeting Programme

Tuesday, 24th September

19:30 Ice break at CENIEH

Wednesday, 25th September

8:00-9:00 Registration

9:00-9:25 WELCOME AND INTRODUCTION

J.M. Parés

9:25-10:10 OPENING LECTURE

M.J. Head, P. L. Gibbard

The Early–Middle Pleistocene transition: a global perspective and focus on the Jaramillo Subchron

10:10-10:25 Coffee break

Session 1: Magnetostratigraphy

Chairman: J.M. Parés

10:25-11:10 OPENING LECTURE

J.E.T. Channell

Quaternary magnetic stratigraphy: More than polarity reversals

11:10-11:30 J. Dinarès-Turell, A. Incarbona

The Early-Middle Pleistocene Transition (MPT): a paleomagnetic and paleoceanographic overview of Mediterranean piston cores from the Sicily Channel margins

11:30-11:50 M. Garcés

A magnetostratigraphy-based chronostratigraphy of the Pliocene-Pleistocene of the Guadix-Baza Basin

11:50-12:10 O. Oms, M. Ghinassi, M. Papini, Y. Libsekal, D. Araia, T. Medin, L. Rook
The Jaramillo chron at Buia (Eritrea, Horn of Africa): an expanded record in fluviolacustrine environments

12:10-12:40 Short discussion

12:40 End of the session
Conference group photo

13:00 Lunch at Taberna de Tanin (behind CENIEH)

Session 2: Radiometric dating methods

Chairman: L. Arnold

14:30-15:15 OPENING LECTURE
B.S. Singer
A Quaternary Geomagnetic Instability Time Scale (GITS) with focus on 40Ar/39Ar dating of geomagnetic field reversals and excursion of the upper Matuyama Chron

15:15-15:35 S. Nomade, H. Guillou, P. Renne, B. Giaccio, G. Scardia, G. Sottili, C. Sprain, V. Scao, G. Zanchetta, C. Kissel, L. Sagnotti,C. Laj, J.-C. Carracedo, P. Messina
Age and duration of the Brunhes/Matuyama and Upper Jaramillo event transitions using 40Ar/39Ar and unspiked K/Ar

15:35-15:55 Á. Rodés
Combined surface exposure and burial dating from cosmogenic 10Be-26Al depth profiles

15:55-15:15 *Coffee break*

16:15-16:35 M. Duval, J.-J. Bahain, C. Falguères, V. Guilarte Moreno, D. Moreno, Q. Shao, P. Voinchet, J. García, K. Martínez
On the challenge of dating late Early Pleistocene hominid occupations by Electron Spin Resonance (ESR): an example from Vallparadís (Spain)

16:35-16:55 M. Demuro, L. Arnold.
Testing the suitability of novel luminescence dating techniques over Early and Middle Pleistocene timescales

16:55-17:10 D. Hoffmann
Potential and limitations of U-series dating for early to middle Pleistocene chronologies

20:00 *Dinner at the Abba Hotel*

Thursday, 26th September

9:00-9:10 M. Garcés
Presentation of the ESF EU-EARTHTIME Research Networking Programme

Session 3: Palaeoclimatology / Palaeoenvironment

Chairman: D. Hoffmann

9:10-9:55 OPENING LECTURE
M.A. Maslin, C. Brierley, C. Tzedakis
Mid-Pleistocene Transition: The great precession versus obliquity debate

9:55-10:15 P. Anadón, O. Oms, V. Riera, R. Julià
Geochemistry of biogenic carbonates as paleoenvironmental tool for the upper Matuyama succession at Barranco León (Baza Basin, Spain)

10:15-10:35 H.-A. Blain, I. Lozano-Fernández, J. M. López-García, M. Bennàsar, G. Cuenca-Bescós
Seasonal rainfall variability during the Early-Middle Pleistocene transition in northern Spain (Atapuerca, Burgos)

10:35-10:55 P. Ferretti, H. Elderfield, M. Greaves, S. J. Crowhurst, I. N. McCave, D. Hodell, A. Piotrowski
Evolution of global ice volume and deep-water temperature in response to changing glacial and orbital boundary conditions during the past 1.5 million years

10:55-11:15 Coffee break

11:15-11:35 S. Joannin, N. Combourieu Nebout, F. Bassinot, O. Peyron
Did the first ice-sheets of the north hemisphere cause rapid climate changes over the Mediterranean region?

11:35-11:55 A. Bertini
The Early-Middle Pleistocene transition: an overview from the terrestrial realm as provided by the Italian pollen records

Session 4: Sedimentary record / Cyclostratigraphy
Chairman: M. Duval

11:55-12:40 OPENING LECTURE
P.L. Gibbard
Fluvial and glacial system responses to the Middle Pleistocene Transition

12:40-13:00 L. Lanci
Pleistocene cyclostratigraphy

13:00-13:20 C. Viseras, S. Pla-Pueyo
Climatic control on palaeohydrology and sediment distribution in the Pleistocene Guadix Basin (Betic Cordillera, Spain)

13:30-15:00 Lunch at Taberna de Tanín

Session 5: Biostratigraphy

Chairman: M. Head

15:00-15:45 OPENING LECTURE
L. Rook
The Early – Middle Pleistocene transition: the Italian large mammal record

15:45-16:05 J. Agustí, H.-A., Blain, O. Oms, I. Lozano, P. Piñero
Biostratigraphic and climatic events in the early-middle Pleistocene transition of Eastern Spain

16:05-16:25 G. Cuenca-Bescós, H.-A. Blain, J. Rofes, I. Lozano-Fernández, J. M. López-García, M. Bennàsar
The biostratigraphic position of the Lower Red Unit of the Sima del Elefante site (TELRU) based upon its small mammal assemblages (Atapuerca, Spain, Early Pleistocene), and the pre-Jaramillo faunas

16:25-16:40 Coffee break

16:40-17:00 J. van der Made
Large mammals and biostratigraphy around the Lower-Middle Pleistocene boundary and the Jaramillo in Europe

17:00-17:20 T. van Kolfschoten, A. K. Markova
Changes in the Central and Eastern European mammalian fauna during the mid-Pleistocene transition

17:20-17:40 B. Martínez-Navarro, J. Madurell-Malapeira, S. Ros-Montoya, Mª P. Espigares, T. Medin, P. Palmqvist
The Epivillafranchian and the arrival of pigs into Europe

17:40-18:20 Discussion

20:00 *Dinner at the Gallego (behind CENIEH)*

Friday, 27th September

Session 6: Human evolution / Archaeology

Chairman: M. Maslin

9:00-9:45 OPENING LECTURE
J.M. Bermúdez de Castro, M. Martinón-Torres
Continuity versus discontinuity of the Early Pleistocene European human populations: The Atapuerca evidence

9:45-10:05 S. Parfitt
The Early Human Colonization of Europe: A view from the North

10:05-10:25 M. Arzarello, J. Arnaud, C. Peretto, A. Potì.
The Pirro Nord site (Apricena, FG, Southern Italy) in the context of the first European peopling: convergences and divergences

10:25-10:45 *Coffee break*

10:45-11:05	J. Rodríguez, G. Rodríguez-Gómez, J. A. Martín-González, A. Mateos *Palaeoecology of mammals as a factor in the distribution of Homo at the end of the Early Pleistocene*
11:05-11:25	M. Sahnouni *Hominid settlements in the Maghreb during the Early and Middle Pleistocene*
11:25-11:45	S. Semaw, M. Rogers, D. Stout *Plio-Pleistocene Archaeology of Gona Study Area, Afar, Ethiopia*
11:45-12:30	Round Table and final discussion
12:30	End of the meeting
12:45	*Lunch at Forum de la Evolución*

Session 0

Welcome and Introduction

J.M. Parés

Jaramillo: More than a simple chron

Opening Lecture

M.J. Head

The Early–Middle Pleistocene transition: a global perspective and focus on the Jaramillo Subchron

Jaramillo: More than a simple chron

Josep M. Parés [1]

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The reversals of the Earth's magnetic field have been known for almost a hundred years, and constitute one of the most fascinating properties of the Earth. Magnetic reversals are best documented by the analysis of marine magnetic anomalies, although at present, our investigations of the geomagnetic polarity record have been successfully carried out in a variety of marine and terrestrial rocks. During the last thirty years, on-land studies and those from deep-sea sediment cores have verified the marine reversal record by furnishing overlapping and correlatable sections. As a result, the so called Global Polarity Time Scale contains more than 270 polarity intervals, spanning almost 190 My. Among these reversals, the Subchron C1r.1n, better known as Jaramillo, was a landmark on the development of the plate tectonics theory in the mid-sixties. B. Dalrymple, at the 1965 Geological Society of America meeting in Kansas City, first reported a short polarity chron, within the upper part of Matuyama, dated as 0.9 Ma, later coined as Jaramillo by Doell and Dalrymple in 1966. That was the smoking gun for the scientists who upon the new paleomagnetic evidence did test the seafloor spreading theory of continental drift. The Subchron was named after the Jaramillo Creek, in the Jemez Mountains of New Mexico, where an extensive volcanic complex is found. Since its discovery, the Jaramillo Subchron has progressively gained popularity in Pleistocene studies on paleontology and archaeology in particular. The age of Jaramillo has been determined using a combination of Ar-Ar, astronomical tuning and $\delta^{18}O$, and it ranges from 1068 ka to 987 ka. When combined with benthic and planktic records, the Jaramillo appears to occur during MIS 27-31. In detail, the structure of the Jaramillo is a bit more complex, as it appears to include a very short reverse polarity interval, as observed in both lavas and deep sea sediments. The Jaramillo Subchron has been used repeatedly in a large number of studies that deal with paleontology and/or archaeology. Nowadays many authors refer to "post-Jaramillo" and "pre-Jaramillo" faunal records, which leads to the question of which localities encompassing both secure fauna and solid magnetostratigraphy contain the Jaramillo Subchron. To better exemplify this situation, we will explore classic European archaeo/paleontological sites including Le Vallonnet (SE France), Untermassfeld (Thüringen, Germany) and Vallparadís (NE Spain), all allegedly having recorded the Jaramillo Subchron.

The Early–Middle Pleistocene transition: a global perspective and focus on the Jaramillo Subchron

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Marked by a progressive increase in the amplitude of climate oscillations and a shift towards a quasi-100 kyr frequency, the Early–Middle Pleistocene transition, sometimes known as the Mid-Pleistocene Transition (or Mid-Pleistocene Revolution) (1.2–0.5 Ma), represents a fundamental shift in the Earth's climate state. The physical and biotic responses to this transition, amplified by the growth of Northern Hemisphere ice sheets, have been profound. Two important paleomagnetic episodes characterize the Mid-Pleistocene Transition, the Jaramillo Subchron (1.07–0.99 Ma) and the Matuyama–Brunhes Chron boundary (773 ka). The latter has been chosen as the primary guide for the Lower–Middle Pleistocene Subseries boundary, partly since it is the approximate midpoint of the Mid-Pleistocene Transition but also because the Matuyama–Brunhes Chron boundary aids global recognition both in marine and terrestrial deposits. Much effort has been expended in characterizing the Lower–Middle Pleistocene boundary in the Mediterranean (especially the Valle di Manche and Montalbano Jonico sections) and Japan (Chiba section) where the three potential Global Boundary Stratotype Sections and Points (GSSPs) are located.

The Jaramillo Subchron has received less concerted attention, but the late Early Pliocene is important in Europe because it saw the progressive transition from the Villafranchian to Galerian mammal faunas, and expansion of hominins into eastern and northern Europe. The Jaramillo Subchron is represented by marine isotope stages (MIS) 31 to 28, with MIS 30 already showing the asymmetrical (saw-tooth) pattern characteristic of climate variability in the Middle Pleistocene. Indeed, while variation in the 40-kyr band (obliquity) remains strong throughout the Mid-Pleistocene Transition, low frequency variability begins at around 1250–1200 kyr (with increased power in the 70-kyr band), which coincides with a progressive increase in global ice volume. Against this backdrop, MIS 31 at the base of the Jaramillo Subchron includes anomalous cooling suggested to be the result of cloud cover caused by an increase in the flux of cosmic rays, this being the consequence of a drop in the Earth's magnetic field intensity.

During the early phase of the Mid-Pleistocene Transition, prior to the Matuyama–Brunhes Chron boundary, a number of climatic and biotic events took place. These include a series of glaciations beginning with MIS 36 and continuing to MIS 22, a major intensification of the East Asian winter monsoon system, intensification of loess deposition in northern Europe, development of open landscapes in western Siberia and spread of large mammals across northern Eurasia, a strong reduction in the North Atlantic thermohaline circulation, and evidence of human-controlled fire. In Europe, the loss of thermophilous plant taxa during the Mid-Pleistocene Transition and indeed throughout the Quaternary is a reminder of the progressive cooling that took place in this region.

Session 1: Magnetostratigraphy

J.E.T. Channell

Quaternary magnetic stratigraphy: More than polarity reversals

J. Dinarès-Turell

The Early-Middle Pleistocene Transition (MPT): a paleomagnetic and paleoceanographic overview of Mediterranean piston cores from the Sicily Channel margins

M. Garcés

A magnetostratigraphy-based chronostratigraphy of the Pliocene-Pleistocene of the Guadix-Baza Basin

O. Oms

The Jaramillo chron at Buia (Eritrea, Horn of Africa): an expanded record in fluviolacustrine environments

Quaternary magnetic stratigraphy: More than polarity reversals

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Improving stratigraphic resolution is one of the great challenges in paleoceanography and in other fields of geoscience including vertebrate paleontology and timescale construction. The unprecedented stratigraphic resolution achievable in Greenland and Antarctic ice cores has led to major advances in climate science, however, ice cores are restricted in time-span and geographic distribution. In Quaternary marine sediments, oxygen isotopes ($d^{18}O$) provide the traditional stratigraphy although, even for benthic data, $d^{18}O$ is not always a synchronous global signal due to variations in temperature and water chemistry. Magnetic polarity stratigraphy is the linchpin of geologic timescales for the last 150 Myrs, mainly because reversals are globally recorded and synchronous on millennial timescales. On the other hand, polarity reversals are only useful for high-resolution correlation in their immediate vicinity, close to polarity chron boundaries. Two other facets of the paleomagnetic record can, however, be used for correlation within polarity chrons. The intensity of the Earth's dipole field has decreased by ~5%/century in the last few hundred years, is a parameter that varies on short timescales, and is manifest globally. Relative paleointensity (RPI) can be recorded by sediments in which (titano)magnetite, in a restricted submicron to few-micron grain-size range, is the sole magnetic mineral. Laboratory-produced magnetizations are used to normalize the intensity of natural remanent magnetization (NRM) for changes in concentration of remanence-carrying grains. "Tandem" correlation of $d^{18}O$ and RPI, facilitated through the *Match* protocol, has been utilized in the North Atlantic and Pacific to generate optimal matches of these two ostensibly global signals in sediment sequences recovered by ocean drilling. The purpose has been ratify the use of RPI as a global correlation tool, and generate reference stacks of RPI and $d^{18}O$ based on these tandem correlations. Superimposed on this $d^{18}O$/RPI variability are geomagnetic excursions, defined here as brief directional aberrations of the main dipole field outside the range of expected secular variation. Although records of magnetic excursions date from the 1960s, the record has become much better resolved in recent years. The number of Brunhes Chron excursions in recent reviews of the subject have reached the 12-17 range, of which only about ~7 are adequately and/or consistently recorded. For the Matuyama Chron, the current inventory of excursions stands at about 10, with one excursion within the Jaramillo Subchron. Magnetic excursions occupy RPI minima, and excursion records with good age control imply millennial-scale or even centennialscale excursion durations. The higher-fidelity excursion records indicate that excursions are essentially paired polarity-reversals flanking virtual geomagnetic poles (VGPs) that reach high latitudes in the opposite hemisphere. Based on these observations, excursions can be considered a feature of the axial dipole field, are therefore manifest globally, and provide a high-resolution stratigraphic tool in addition to $d^{18}O$ and RPI.

The Early-Middle Pleistocene Transition (MPT): a paleomagnetic and paleoceanographic overview of Mediterranean piston cores from the Sicily Channel margins

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Mediterranean piston cores LC07 (38°08.72'N, 10°04.73'E; length 23.66 m, water depth 488 m) and LC10 (35°12.77'N, 16°34.88'E; length 19.86 m, water depth 1322 m) were collected by the R/V Marion Dufresne in 1995 (MAST II PALAEOFLUX Program) from a location north of the Skerki Channel at the western side of the Sicily Strait (LC07), and on a bank north of Heron Valley at the eastern side of the Sicily Strait (LC10).The location of these two cores, with contrasting lithology, at different settings on either side of the Strait of Sicily, enables evaluation of the response of sedimentary processes and assessment of the link to climatic forcing. We first will review the chronologic constraints based on standard magnetostratigraphy and sedimentary paleointesity proxies along oxygen isotope stratigraphy (Dinarès-Turell *et al*., 2002, 2003) that indicate that the studied records extend the upper part of the Matuyama and the Brunhes chrons (including the record of the Jaramillo subchron in LC07). Secondly, the rock magnetic proxies that appear to correlate with indices of climatic change together with quantitative analyses of calcareous nannofossils and planktonic foraminifera (Incarbona *et al.*, 2008, 2013) will be presented. Collectively the dataset allows deciphering the paleoclimatic signature from these Mediterranean records. The rock magnetic variations appear to be related to the magnetite grain size, with glacial periods dominated by the relatively coarse magnetite grains due to enhanced African dust input, alternating with fine-grained magnetite formed by magnetotactic bacteria during interglacials High-resolution planktonic foraminifera data, collected every ~780 years, from core LC10 recovered in the Ionian Sea (Incarbona *et al.*, 2013) allowed us to speculate on the surface marine ecosystem evolution during the mid-Pleistocene transition (MPT), between 1.2 and 0.9 Ma.

Dinarès-Turell, J., Sagnotti, L. and Roberts, A.P. (2002). Relative geomagnetic paleointensity from the Jaramillo subchron to the Matuyama/Brunhes boundary as recorded in a Mediterranean piston core. *Earth Planet. Sci. Letters*, 194, 327-341.

Dinarès-Turell, J., Hoogakker, B.A.A., Roberts, A. P., Rohling E.J. and Sagnotti, L. (2003) Quaternary climatic control of biogenic magnetite production and eolian dust input in cores from the Mediterranean Sea. *Palaeogeography, Palaeoclimatology, Palaeocology*. 190, 195-209.

Incarbona, A., Di Stefano, E., Sprovieri, R., Bonomo, S., Censi. P., Dinarès-Turell, J. and Spoto, S. (2008). Variability in the vertical structure of the water column and paleoproductivity reconstruction in the central-western Mediterranean during the late Pleistocene. *Mar. Micropal*. 69, 26-41*, doi:* 10.1016/j.marmicro.2007.11.007

Incarbona, A., Dinarès-Turell, J., Di Stefano, E., Ippolito, G., Pelosi, N. And Sprovieri, R. (2013). Orbital Variations in Planktonic Foraminifera Assemblages from the Ionian Sea during the Middle Pleistocene Transition. *Palaeogeogr., Palaeoclimatol., Palaeocol*.., 369, 303-312, http://dx.doi.org/10.1016/j.palaeo.2012.10.039

A magnetostratigraphy-based chronostratigraphy of the Pliocene-Pleistocene of the Guadix-Baza Basin

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The Guadix-Baza Basin underwent a internally drained basin in the late Messinian (Hüsing et al., 2010), and filled with up to 300 m of Pliocene-Pleistocene alluvial-lacustrine sequence until its overfilling and fluvial capture during the late Pleistocene (Fernández et al., 1996). The abundance and significance of fossil vertebrate discoveries encouraged in the 90's the development of a magnetostratigraphy-based chronology. Since then a considerable number of magnetostratigraphic studies have been published, while the chronostratigraphic debate remains on the pre or post-Olduvai age of a number of localities in the Orce region. In the origin of the controversy lies the fact that most published magnetostratigraphic sections have thicknesses which rarely exceed 100 m, often yielding few polarity zones. As a result, magnetostratigraphic correlations have necessarily relied on biochronological constraints, and circular reasoning has propagated into the literature with regard to the apparent magnetostratigraphic calibration of the paleontological record.

Here we review the bio-magnetostratigraphic data available in the Guadix-Baza basin in an attempt to organize the information according to their source of uncertainty. In this respect, explicit discrimination is made between correlations based on an external (biostratigraphic or radiometric) age control and those based on the best fit with the GPTS.

A magnetostratigraphic correlation with the GPTS is robust as long as a unique match with the GPTS is found independently from biochronological constraints. But finding an unambiguous correlation solely based in the smoothest derived sediment-accumulation rates is only achievable when a long and characteristic pattern of reversals is recovered. A limited number of magnetostratigraphic studies in the Guadix-Baza basin have yielded a pattern of reversals long enough to stablish an independent correlation with the GPTS (Arribas et al., 2009; Garcés et al., 1997; Oms et al., 1999). They constitute a robust chronostratigraphic framework to link other records within the basin on the basis of local lithostratigraphic and biostratigraphic arguments.

Arribas, A. et al. (2009). A Mammalian Lost World in Southwest Europe during the Late Pliocene. *PLoS One*, *4*(9), e7127.

Fernández, J. et al., (1996). Stratigraphic architecture of the Neogene basins in the central sector of the Betic Cordillera (Spain): tectonic control and base-level changes. In P. F. Friend & C. Dabrio (Eds.), *Tertiary basins of Spain: the stratigraphic record of crustal kinematics* (pp. 353–365). Cambridge University Press.

Garcés, M. et al., (1997). Late Pliocene continental magnetochronology in the Guadix-Baza Basin (Betic Ranges , Spain). *Earth and Planetary Science Letters*, *146*, 677–687.

Hüsing, S. et al., (2010). On the late Miocene closure of the Mediterranean-Atlantic gateway through the Guadix basin (southern Spain). *Palaeogeography Palaeoclimatology Palaeoecology*, *291*(3-4), 167–179.

Oms, O. et al., (1999). Refinements of the European Mammal Biochronology from the Magnetic Polarity Record of the Plio-Pleistocene Zújar Section, Guadix-Baza Basin, SE Spain. *Quaternary Research*, *51*, 94–103.

The Jaramillo chron at Buia (Eritrea, Horn of Africa): an expanded record in fluviolacustrine environments

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Buya area is located in the Danakil Depression, close to the Red Sea, some 90 km to the south of the city of Massawa. The analized rocks are found NW of Aalat mount (238 m), one of the reliefs separating the Curbelu plateau from the Samoti Plain, located to the west and east, respectively. The strata there found are part of the Dandiero group, which infill the homonymous basin. The sedimentary succession is build up by several stratigraphic units (from base to top): Bukra sand and gravel, Aalat formation, Wara sand and gravel, Goreya Formation and Aro sands. The Aalat Formation contains the paleoantropological site of Buia, which is remarkable not only for bearing *Homo* remains, but also a large list of other vertebrate species. The Jaramillo chron was previously studied in Buia by several works, summarized by Albianelli and Napoleone in 2004.

Our study integrates improved geological work (mapping, litostratigraphy and sedimentology) with new magnetostratigraphic data. The resulting dataset permits detailed location of paleomagnetic samples and reversals and the control of tectonic repetitions. These points are of particular interest in thick sections. The thickest Aalat section (285 m) displays three polarity chrons: a 70 m lower normal one (N1), a 165 m reverse one (R) and 50 m upper normal one (N2). The quality of paleomagnetic data, and its crossing with absolute dating (fission track) and vertebrate paleontology, provide a robust correlation of the recorded magnetostratigraphy. Thus, N1 is C1r.1n (Jaramillo), R is C1r.1r and N2 is C1n (Brunhes), so that extremely high accumulation rates are recorded at Buia.

The facies-related paleonvironmental sucession also provides discussion on climate variations in the Lower-Middle Pleistocene transition in Africa and its effects in *Homo* evolution.

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Session 2: Radiometric dating methods.

B.S. Singer

A Quaternary Geomagnetic Instability Time Scale (GITS) with focus on 40Ar/39Ar dating of geomagnetic field reversals and excursion of the upper Matuyama Chron

S. Nomade

Age and duration of the Brunhes/Matuyama and Upper Jaramillo event transitions using 40Ar/39Ar and unspiked K/Ar

Á. Rodés

Combined surface exposure and burial dating from cosmogenic 10Be-26Al depth profiles

M. Duval

On the challenge of dating late Early Pleistocene hominid occupations by Electron Spin Resonance (ESR): an example from Vallparadís (Spain)

M. Demuro

Testing the suitability of novel luminescence dating techniques over Early and Middle Pleistocene timescales

D. Hoffmann

Potential and limitations of U-series dating for early to middle Pleistocene chronologies

A Quaternary Geomagnetic Instability Time Scale (GITS) with focus on $^{40}Ar/^{39}Ar$ dating of geomagnetic field reversals and excursion of the upper Matuyama Chron

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Reversals and excursions of Earth's geomagnetic field create marker horizons that are readily detected in sedimentary and volcanic rocks worldwide. An accurate and precise chronology of these geomagnetic field instabilities is fundamental to understanding several aspects of Quaternary climate, dynamo processes, and evolution of Earth's surface. For example, stratigraphic correlation between marine sediment and polar ice records of climate change across the cryospheres benefits from a highly resolved record of reversals and excursions. The temporal patterns of dynamo behavior may reflect physical interactions between the molten outer core and the solid inner core or lowermost mantle. These interactions may control reversal frequency and shape the weak magnetic fields that arise during successive dynamo instabilities. Moreover, weakening of the axial dipole during reversals and excursions enhances the production of cosmogenic isotopes that are used in sediment and ice core stratigraphy and surface exposure dating. The Geomagnetic Instability Time Scale (GITS) is based on the direct dating of transitional polarity states recorded by lava flows using the $^{40}Ar/^{39}Ar$ method, in parallel with astrochronologic age models of marine sediments in which oxygen isotope and magnetic records have been obtained. A review of data from Quaternary lava flows and sediments gives rise to a GITS that comprises 10 polarity reversals and 27 excursions that occurred during the past 2.6 million years. Nine of the ten reversals bounding chrons and subchrons are associated with $^{40}Ar/^{39}Ar$ ages of transitionally-magnetized lava flows. The tenth, the Guass-Matuyama chron boundary, is tightly bracketed by $^{40}Ar/^{39}Ar$ dated ash deposits. Of the 27 well-documented geomagnetic field instabilities manifest as short-lived excursions, 14 occurred during the Matuyama chron and 13 during the Brunhes chron. Nineteen excursions have been dated directly using the $^{40}Ar/^{39}Ar$ method on transitionally-magnetized volcanic rocks and these form the backbone of the GITS. Excursions are clearly not the rare phenomena once thought. Rather, during the Quaternary period, they occur nearly three times as often as full polarity reversals.

In this presentation I will address analytical issues, including the size and consistency of system blanks, that have led to the recognition of minor (1%) discrepencies between the $^{40}Ar/^{39}Ar$ age for a particular reversal or excursion and the best astrochronologic estimates from ODP sediment cores. For example, we have carefully re-analyzed lava flows from Haleakala volcano, Maui, Hawaii that record in detail the Matuyama-Brunhes polarity reversal. These new measurements: (1) have been undertaken using a mass spectrometer system with blanks an order of magnitude smaller than what was common a decade ago, and (2) take advantage of the modern astrochronologic calibration of 28.201 Ma for the age of the Fish Canyon sanidine standard. The results thus far yield an $^{40}Ar/^{39}Ar$ age of 772 ± 11 ka for the reversal that is identical to the most precise and accurate astrochronologic age of 773 ± 1 ka for this reversal from ODP cores. Similarly recent experiments on sanidine from the transitionally magnetized Cerro Santa Rosa I rhyolite dome give an age of 932 ± 5 ka that is in perfect agreement with the astrochronologic age for this excursion in North Atlantic ODP cores. Simply re-calculating published $^{40}Ar/^{39}Ar$ ages for these lavas using the 28.201 Ma FCs standard age gives inaccuate results, for example an age of 942 ka for the Santa Rosa excursion. Work underway aims at refining the $^{40}Ar/^{39}Ar$ ages that underpin the entire GITS, by eliminating the bias between the radioisotopic and astrochronologically determined ages for several reversals and excursions. This includes new experiments on the lava flows in Tahiti and Southern Argentina that record in detail the polarity reversals that bound the Jaramillo Normal subchron.

Age and duration of the Brunhes/Matuyama and Upper Jaramillo event transitions using $^{40}Ar/^{39}Ar$ and unspiked K/Ar

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We have studied in detail the Pleistocene lacustrine sequence of the Sulmona basin (central Italy) that harbors a high-resolution record of the B/M polarity transition (e.g. in a stratigraphic thickness of about 1.6 m according to Scardia et al., 2011) as well as a full glacial-interglacial-glacial record ascribed to the MIS20–MIS18 interval (Giaccio et al., 2013). This lacustrine sequence consists of a low-energy distal clay-rich carbonate bearing a large number of tephra sourced from the peri-Tyrrhenian, ultra-potassic volcanic complexes located *c.a.* 80 km westward. According to the paleoenvironnemental records available at Sulmona, the B/M polarity transition falls within the earliest and warmest period of MIS 19 in contradiction with other records which place it in the later portion of this stage (Channell et al., 2010). Based on radio-isotopic constraints provided by laser single-grain $^{40}Ar/^{39}Ar$ ages on three tephra layers that bracketed the transition we determined an accurate and precise age and duration for the B/M polarity transition. The $^{40}Ar/^{39}Ar$ ages on the tephra layers were obtained independently in two laboratories (LSCE in Gif-Sur-Yvette and the Berkeley Geochronology Center, USA).

$^{40}Ar/^{39}Ar$ and the unspiked K-Ar techniques have been combined to date the Upper Jaramillo/Matuyama transition recorded in a lava sequence from Tenerife Island. Both methods were conducted on groundmass splits off our transitionally magnetized flows. The age obtained, following this approach is 992 ± 6 ka relative to FCT 28.02 Ma.

For both transitions the age and duration are estimated in the light of the recent re-evaluation of the $^{40}Ar/^{39}Ar$ flux standard ages as well as of the ^{40}K total decay constant (see Kuiper et al., 2008 and Renne et al., 2011) and compared with their astronomically calibrated ages (Channell et al., 2010) and with the ice chronologies in the case of the B/M (Dreyfus et al., 2008).

Channell et al., (2010) *Geochemistry, Geophysics, Geosystems* 11, Q0AA12; Dreyfus et al., (2008) *Earth Planetary Science Letters* 274, 151–156; Giaccio et al., (2013), *Journal of Quaternary Science*, in press; Kuiper et al., (2008) *Science*, 320, 500–504; Renne et al., (2011) *Geochimica et Cosmochimica Acta*, 75, 5097-5100. Scardia et al., (2012) EGU Fall meeting, 2012-3583

Combined surface exposure and burial dating from cosmogenic ^{10}Be-^{26}Al depth profiles.

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Cosmogenic nuclides can be used to date sediments and landforms in two different ways: surface exposure dating and burial dating. The accumulation of cosmogenic nuclides near the surface usually reach an steady state after some hundred thousand years. When sediments are buried (>5 m) after exposition at the surface, the radioactive cosmogenic nuclides decay and the depleted $^{26}Al/^{10}Be$ ratio can be used as a geochronometer up to 5-10 Ma. Cosmonuclide depth-profiles are used to calculate the exposure age of landforms, the rates at which erosion has affected them since their formation and the paleo-erosion rate in the source area. However, two difficulties are typically encountered: 1) old deposits or strongly affected by cosmonuclide inheritance often appear to be saturated, and 2) a full propagation of uncertainties often yields poorly constrained ages. We show how to combine surface-exposure-dating and burial-dating techniques in the same profile to get more accurate age results and to constrain the extent of pre-depositional burial periods. Paired 10Be and 26Al depth-profiles measured in alluvial deposits of SE Iberia are presented as natural examples.

On the challenge of dating late Early Pleistocene hominid occupations by Electron Spin Resonance (ESR): an example from Vallparadís (Spain)

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Dating Early Pleistocene archaeological sites in non-volcanic contexts is quite a challenge because only a few numerical dating techniques are available for this age range. Together with cosmogenic nuclides, and perhaps Luminescence, electron spin resonance (ESR) is one of the very few potential candidates. This method has the advantage to be possibly applied to a wide range of materials and to cover, thus, any geological context, making it as the favorite method to date early hominid occupations in Europe (e.g. Bahain et al., 2007; Falguères, 2003; Duval et al., 2012).

Excavated between 2005 and 2007, the site of Vallparadís (Terrassa, Spain) has yielded an abundant and diversified fauna associated with a rich Mode 1 industry (Martínez et al., 2010), mainly located in the unit 7. Palaeomagnetic studies indicated that this archeological occupation was included inside one reverse magnetozone and located between two normal magnetozones. The combination of these results with those derived from the biochronology suggested that unit 7 was very likely constrained by the end of Jaramillo and the beginning of Brunhes chrons (Madurell-Malapeira et al., 2010), i.e. somewhere between 0.99 and 0.78 Ma.

In order to further complete this chronostratigraphical framework, several ESR samples were collected. Preliminary ESR dating of optically bleached sedimentary quartz grains and combined U-series/ESR dating of fossil teeth samples provided an initial ESR chronology of ~0.8 Ma (Martinez et al., 2010; Duval et al., 2011) for Vallparadís. These results, in good agreement with the previous chronological framework, helped to place the site as coeval with Atapuerca Gran Dolina-TD6 (Burgos, Spain). Additional tooth samples were collected later and further analysis were performed on the previous samples in order to complete the initial data set. Final ESR results are presented, showing the potential, as well as the actual limitations, of the ESR method to date late Early Pleistocene sites.

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Testing the suitability of novel luminescence dating techniques over Early and Middle Pleistocene timescales

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Establishing reliable and precise numerical chronologies at Middle and Early Pleistocene fossil sites has traditionally proved challenging for many conventional geochronological techniques, including optically stimulated luminescence (OSL) dating. Traditional quartz OSL methods are effectively limited in their application to Late Pleistocene sedimentary deposits because the signal used for dating becomes saturated with respect to radiation dose over longer timescales. However, the last few years has seen the emergence of several "extended-range" luminescence dating techniques that make use of alternative signals with significantly higher dose saturation limits. Such approaches provide new possibilities to push back luminescence dating boundaries and considerable efforts are now being focussed on assessing the applicability of these novel approaches across different sedimentary environments.

Here we present results of ongoing research into improving Early-to-Middle Pleistocene chronological frameworks at several archaeological and paleontological sites across the Iberian Peninsula using a range of novel luminescence dating techniques (single-grain OSL dating of "supergrains", thermally transferred OSL (TT-OSL) dating, and post-infrared infrared stimulated luminescence (pIR-IRSL) dating). To test the suitability of these techniques we have adopted two approaches: (i) comparisons with independent age control obtained using other numerical or relative dating methods; and (ii) internal checks on dating consistency using a comparative luminescence dating approach involving the measurement of several independent signals, different mineral types, and different scales of analysis (single versus multiple grain). The latest luminescence dating results obtained at the Atapuerca sites of Galería, Sima del Elefante and Gran Dolina are in general agreement with independent chronological control over an age range spanning at least 250–800 ka. Replicate ages obtained at the Early-Middle Pleistocene Guadix-Baza palaeontological site of Huéscar-1 using five different extended-range luminescence techniques also display a high degree of internal consistency. However, these ages are considerably younger than anticipated from biochronological associations at Huéscar-1, which could suggest that some of the fossils are not contemporaneous with the dated sediments at this site.

Overall, our results highlight the potential for using newly developed luminescence dating techniques to fill in the chronological 'gap' over late Early to late Middle Pleistocene timescales, particularly in low dose rate environments. Each of these novel luminescence methodologies has its own advantages and limitations but, when applied in conjunction, they represent a potentially versatile geochronological toolkit capable of covering a dynamic time range. Additional known-age comparison studies are now needed to assess the broader suitability of these techniques in other dating contexts and across other geological provinces.

Potential and limitations of U-series dating for early to middle Pleistocene chronologies

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U-series dating of secondary carbonates such as speleothems, travertines or corals using high precision mass spectrometry is an important geochonological technique. However, early to middle Pleistocene ages are still analytical challenges for both U-Th and U-Pb dating techniques because U-Th activity ratios are very close to secular equilibrium, and the amount of radiogenic Pb is still small compared to common Pb backgrounds. Higher analytical precisions, smaller detection limits and thus smaller sample sizes that can be analysed could help to extend the dating range of U-Th and U-Pb dating.

Some recent developments in multi collector (MC) inductively coupled plasma mass spectrometry (ICPMS) U-Th and U-Pb dating will be discussed. Technical advances in MC-ICPMS lead to higher analytical precisions potentially enabling U-Th dating beyond 600ka. U-Pb isochron dating has been successfullly applied to speleothems younger than 1 Ma. Potential and limitations of U-series dating for early to middle Pleistocene chronologies will be briefly discussed with respect to precision and accuracy of MC-ICPMS methods specifically in the light of instrumental biases.

Session 3: Palaeoclimatology / Palaeoenvironment

M.A. Maslin

Mid-Pleistocene Transition: The great precession versus obliquity debate

P. Anadón

Geochemistry of biogenic carbonates as paleoenvironmental tool for the upper Matuyama succession at Barranco León (Baza Basin, Spain)

H.-A. Blain

Seasonal rainfall variability during the Early-Middle Pleistocene transition in northern Spain (Atapuerca, Burgos)

P. Ferretti

Evolution of global ice volume and deep-water temperature in response to changing glacial and orbital boundary conditions during the past 1.5 million years

S. Joannin

Did the first ice-sheets of the north hemisphere cause rapid climate changes over the Mediterranean region?

A. Bertini

The Early-Middle Pleistocene transition: an overview from the terrestrial realm as provided by the Italian pollen records

Mid-Pleistocene Transition: The great precession verses obliquity debate

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The Mid-Pleistocene Transition (MPT) is the term used to describe the prolongation and intensification of glacial-interglacial climate cycles that initiated after 900 ka. During the transition glacial-interglacial cycles shift from lasting ~41,000 years to ~100,000 year. Moreover the structure of the glacial-interglacial cycles shifts from smooth to more abrupt 'saw-toothed' like transitions. Despite eccentricity having by far the weakest influence on insolation received at the Earth's surface of any of the orbital parameters; it is often assumed to be the primary driver of the post MPT 100,000 year climate cycles because of the similarity in duration. The traditional solution to this is to call for a highly nonlinear response by the global climate system to eccentricity. This 'eccentricity myth' is due to an artefact of spectral analysis which means that the last 8 glacial-interglacial average out at about 100,000 years in length despite ranging from 80,000 to 120,000 years. With the realisation that eccentricity is not the major driving force a debate has emerged to whether precession or obliquity controlled the timing of the most recent glacial-interglacial cycles. Huybers and Wunsch (2005), Huybers (2007; 2009) argue that post MPT deglaciations occur every second or third obliquity cycle. While Ridgwell, et al. (1999) and Maslin and Ridgwell (2005) argue that deglaciation occurred every four or five precessional cycle. Fundamental to their model was the occurrence of a relatively weak precessional peak allowing for a much more intense glaciation which subsequently created a rapid deglaciation through the sea level-ice sheet feedback mechanism. This also provided an explanation of the shift during the MPT from a two-state solution (Glacial and Interglacial) to a three-state solution (Deep-glacial, Glacial and Interglacial). Subsequently Huybers (2011) suggested a combination of obliquity and precession. Our aim here is to review the current theories of the causes of the MPT and the role of orbital forcing.

Geochemistry of biogenic carbonates as paleoenvironmental tool for the upper Matuyama succession at Barranco León (Baza Basin, Spain)

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The Barranco León is located in the NE marginal area of the Plio-Pleistocene Baza Basin (Southern Spain). The Barranco León BL 5 mammal site has delivered abundant archeological tools and a hominid teeth; the age ascribed to this site is comprised between the Olduvai and Jaramillo subchrons, based on magnetostratigraphy, biostratigraphy and ERS dating. The studied BL section, which includes the BL5 site, is formed, from base to top, by dark sandy mudstones and lutites with interbedded sandy marls. The lower part of the dark sandy mudstones contains a brackish fauna with forams and *Cerastoderma*. The sands and gravels of BL5-D overlie the dark-dominated interval. This level, with an erosive base, contains intraformational limestone clasts and the archaeological tools consisting of Mesozoic limestones and cherts. Sandy carbonate mudstones and an interbedded layer of sandy lutites form the upper part of the excavation sequence.

Stable isotope ($\delta^{13}C$, $\delta^{18}O$) and trace element analyses on ostracod and mollusk shells have been performed in order to depict the paleoenvironmental changes recorded in the sequence. Moreover, indications on provenance for waters have been obtained from $^{87}Sr/^{86}Sr$ ratios from shells and opercula from mollusks. The results indicate a significant paleoenvironmental change recorded to the base of the trench, above the *Cerastoderma* bed, by both the faunal change towards a fresher water mollusk fauna and a variation in the geochemical signatures. The isotopic composition of the biogenic carbonates shows a strong correlation between $\delta^{13}C$ and $\delta^{18}O$, which is noticeable for some gastropod shells. This correlation is a characteristic feature of closed lake settings. In our case, the more negative isotopic values reflect the input of meteoric waters and the more positive ones the carbonates formed in the more isotopically concentrated waters. Some of the more negative isotopic values correspond to biogenic carbonates from the BL-5 level. These values correspond to isotopically diluted waters, although the trace element data and the faunal elements indicate oligosaline to mesosaline waters. Moreover, the presence in BL-5 of shells from *Melanopsis tuberculata*, a termophilous gastropod, suggests the input of oligosaline waters with a thermal constituent. The available geochemical data indicate an earlier stage of varying influence of several water types under changing water level in a closed lake recorded in the base of the studied sequence (*Cerastoderma* level). The overlying levels record a through flowing open lacustrine environment mainly fed by meteoric saline ground waters with minor inputs of stream waters.

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Seasonal rainfall variability during the Early-Middle Pleistocene transition in northern Spain (Atapuerca, Burgos)

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The Sierra de Atapuerca lies about 1,080 m above sea level, dominating the now flat landscape of the Castilian grain-growing plains, irrigated by the River Arlanzón near the village of Ibeas de Juarros, located 14 km east of the city of Burgos. Atapuerca is best-known for its complete, anthropological, cultural and palaeontological record, in a complex cave system. The cave sediments of Atapuerca represent a nearly complete, composite-stratigraphic section that ranges from the late Early Pleistocene to the end of the Late Pleistocene in the Iberian Peninsula. The two longest sections from this complex, Sima del Elefante and Gran Dolina caves, are Early to Middle Pleistocene in age, and are extremely rich in faunal remains: amphibians, reptiles, birds and mammals (bats, insectivores, lagomorphs, rodents, , in addition to primates, carnivores, and ungulates,). The Sima del Elefante lower stratigraphic section (Trinchera Elefante lower Red Unit or TE-LRU) ranges from the bottom of the sequence up to unit TE14 (TE7-TE14). Cosmogenic nuclide analysis is consistent with the biostratigraphic age, level TE9 being dated to ~1.2 Ma. Gran Dolina or Trinchera Dolina (TD) has a vertical section 18 m thick that is divided into 11 lithostratigraphic levels (TD4-TD10) dated roughly to between 1 Ma and 250 ka. The TD section contains a good record of the Early-Middle Pleistocene transition. In the Mediterranean area which is climatically stressed by limited water resources and extreme heat, variations of precipitation are known to play a crucial role in the ecosystems and environment. We investigate long-term yearly variations in rainfall throughout the year during the Early-Middle Pleistocene transition; a major climatic and biotic event. By applying the mutual climatic range method to amphibian and squamate reptile assemblages, it has been possible to quantify winter/summer precipitation throughout the long terrestrial sequences of Gran Dolina and Sima del Elefante (Sierra de Atapuerca, Burgos, Spain).

Throughout the two sequences, climate seems to have maintained a Mediterranean character with low summer precipitation and rather mild winter temperatures. However, seasonal trends are brought to light. Winter precipitation (DJF) seems to be related with an evolution in mean annual temperature (MAT). Warmer periods correspond to lower DJF and colder periods to higher DJF. Such a pattern seems to be congruent with the North Atlantic Oscillation (NAO), the dominant mode of atmospheric variability in the North Atlantic region, that associates drying in the Mediterranean area with increasing anticyclonic circulation over the region which causes a northward shift of the mid-latitude storm track. To the contrary, no pattern in relation with MAT is visible for summer precipitation (JJA) throughout the sequence. Nevertheless, after the Mid-Brunhes Event (i.e. 450.000 years), some stronger decreases in summer precipitation are reported after each "interglacial" temperature peaks (MIS 11, MIS 9 and MIS 7).

Evolution of global ice volume and deep-water temperature in response to changing glacial and orbital boundary conditions during the past 1.5 million years

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A fundamental feature of Earth's climate during the Pleistocene is the Mid-Pleistocene Transition (MPT), between ~1250 and 650 ka, when quasi-periodic (~100 kyr), high-amplitude glacial variability developed in the absence of any significant change in the character of orbital forcing, leading to the establishment of the characteristic pattern of late Pleistocene climate variability. A coherent explanation for this transition has eluded palaeoclimatologists for well over 30 years. A hindrance to furthering a quantitative understanding of the MPT is probably the fact the intensification of the glacial regime during this transition has been inferred by an increase in glacial benthic $d^{18}O$ from Marine Isotope Stage (MIS) 38 to 16. However, changes in global ice volume are not the only cause of oxygen isotope variations in foraminifera. For any given species of benthic foraminifera, variations in the $d^{18}O$ of its calcite test reflect some combination of a deep-water temperature component and a sea water-$\delta^{18}O$ component, and the latter may reflect a combination of a global ice volume signal and a local hydrographic signal relating, for example, to changes in the proportions of deep-water with different T - $\delta^{18}O$ signature bathing the core site.

Determining how much each of these components contributed to any given benthic $d^{18}O$ record encompassing the MPT has proven difficult because the $d^{18}O_{calcite}$ signal from ice sheets and temperature likely varied over time and space, and because deep-water masses have differing $d^{18}O$ signals. However, if we are to understand the two key elements of Earth's climate system - ice sheets and ocean heat storage – during this critical interval of climate evolution, we must also distinguish between these two controls: changes in global ice volume and temperature.

We have deconvolved the deep-water temperature and ice-volume components encrypted in $d^{18}O$ of benthic foraminifera by using an independent temperature proxy, magnesium/calcium ratios, combined with oxygen isotope analyses from a deep-sea core recovered in the Southern Hemisphere (Ocean Drilling Program Site 1123) (Elderfield et al., 2012).

Our results support the long-standing notion that global ice-sheets during the maxima of the 41 kyr cycles were smaller than during the maxima of the 100 kyr cycles. Our temperature record presents no evidence of a pattern of gradual cooling associated with the MPT: on the contrary, the deep sea cooled to nearly freezing temperatures early in any given glacial cycle, whereas global ice volume typically increased gradually. Finally, we have defined the timing of initiation of the MPT as an abrupt event centered on MIS 24 to 22 (the '900 ka event') and, although speculative, we have advanced the hypothesis that expansion of the Antarctic Ice Sheet might have had a role in generating the increase in global ice volume during this time.

Elderfield, H., Ferretti, P., Greaves, M., Crowhurst, S.J., McCave, I.N., Hodell, D., Piotrowski, A. 2012: Evolution of ocean temperature and ice volume through the Mid-Pleistocene Climate Transition. *Science* 337, 704-709.

Did the first ice-sheets of the north hemisphere cause rapid climate changes over the Mediterranean region?

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During the Mid Pleistocene Transition (MPT), climate cycles changed in duration and in amplitude due to a switch in the response of the climate system to orbital parameters (obliquity then precession). This change had a strong, long-term impact on the particularly sensitive ecosystems of the Mediterranean region. At the sub-Milankovitch scale, Tzedakis (2007) illustrated the precession impact by applying wavelet analysis to a pollen-based vegetation reconstruction in Greece. Joannin et al. (2011) have more directly shown the precession influence over pollen-based successions of vegetation recorded in the ODP 976 marine core, exerted through precipitation changes as determined by pollen-based climate quantification.

The switch of orbital forcing during the MPT also caused the build-up of big northern hemisphere ice-sheets along the 100-kyr cycles. These ice-volume increases however are marked by instabilities resulting in rapid climate changes affecting Mediterranean terrestrial ecosystems (Combourieu-Nebout et al., 2002). Considering that the anthropogenic increase in $p\mathrm{CO_2}$ is about to drive the climate system towards warmer conditions and may eventually lead it in the mode of the 41-kyr climate cycles, it is thus time to consider the possibility of future rapid climate changes under MPT-like conditions. Until recently, palaeoenvironmental data did not allow their detection, nor the climate models. It is indeed theoretically uncertain whether the instabilities of small ice-sheets could cause rapid climate changes impacting the northern hemisphere.

However, the temporal resolution of recent studies is now able to record cold events from deep marine cores in the northern Atlantic (e. g. Hernández-Almeida et al., 2012a-b). This encourages the reassessment of terrestrial records in the Mediterranean region to assess instabilities of the first ice-sheets and the impacts at mid-latitudes of rapid climate changes in a warm climate mode.

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The Early-Middle Pleistocene transition: an overview from the terrestrial realm as provided by the Italian pollen records

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High-resolution pollen analyses have been conducted on San Lorenzo Pleistocene lacustrine deposits that outcrop in the northern area of the Sant'Arcangelo Basin (Basilicata, southern Italy). A previous pilot facies analysis and biochronological study permitted to define the stratigraphical and palaeoenvironmental context of the 200 m of thinly bedded claystone and silty claystone with sandstone, carbonate and volcanoclastic intercalations (Sabato et al., 2005).

The main pollen record starts just before the Jaramillo subchron and extends to just before the beginning of the Brunhes chron. An additional shorter pollen record, from a nearby succession, provides information on the basal Brunhes. Alternating spread of deciduous broad-leaved forests and open vegetation shows remarkably parallel global glacial/interglacial cycles. Herbs, including steppe taxa, spread when humidity and temperature decreased, while arboreal taxa expanded when the conditions grew warmer and more humid. The floristic content and vegetal assemblages are compared with those from the adjacent Montalbano Jonico marine section (Joannin et al.,2008; Ciaranfi et al., 2013) as well as from more distant sites (e.g. Bertini, 2010, and reference therein) to single out major disappearances or significant demises in modern extra-Mediterranean subtropical to warm-temperate taxa. The disappearance of *Tsuga* in the course of the Brunhes after some acme phases during the Jaramillo is specifically analyzed with conjunction to major changes of periodicity and amplitude of the glacial-interglacial cycles from 41 ka to approximately 100 ka (e.g. Bertini, 2010; Mazza & Bertini, 2013).

Finally, major palaeoclimatic and palaeoenvironmental changes in the Italian peninsula are discussed in relation to geographical gradients and contexts for a better understanding of the primary driving factors responsible for the evolution and dispersal of early Pleistocene human populations. The integration of chronologically well-defined high-resolution terrestrial and marine long pollen successions provides new insights into the response of vegetation to orbital and suborbital climate variability for the period known as 'Mid-Pleistocene Revolution'.

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Sabato, L., Bertini, A., Masini, F., Albianelli, A., Napoleone, G., Pieri, P., 2005: The lower and middle Pleistocene geological record of the San Lorenzo lacustrine sequence in Sant'Arcangelo Basin. (Southern Apennines, Italy). *Quaternary International,*131, 59-69.

Session 4: Sedimentary record / cyclostratigraphy

P.L. Gibbard

Fluvial and glacial system responses to the Middle Pleistocene Transition

L. Lanci

Pleistocene cyclostratigraphy

S. Pla

Climatic control on palaeohydrology and sediment distribution in the Pleistocene Guadix Basin (Betic Cordillera, Spain)

Fluvial and glacial system responses to the Middle Pleistocene Transition

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The Quaternary is characterised by large amplitude climatic fluctuations, one of the most striking consequences of which are intervals of expansion of ice sheets into lowland present-day temperate regions, especially in mid-northern latitudes. These climatic oscillations produced a major impact on the land surface of Europe and beyond, where geomorphological processes have operated to create a topography that bears the legacy of these multi-phased events.

Examination of the evidence of glacier extent accumulated in the *Quaternary Glaciations—Extent and Chronology* project (second edition, 2011) demonstrates the current state of knowledge. Today the evidence from both the land and ocean-core sequences indicates that the major glaciations, rather than occurring throughout the 2.5 my of the Quaternary, are in fact restricted to the last 1 my - 800 ky or less. This is not to say that glaciation did not occur earlier, indeed glaciation limited to higher latitudes or mountain massifs certainly occurred throughout the period and even before, particularly in the Rocky Mountains, but also in eastern North America. Moreover, evidence of extensive ice-rafting, an indication that glaciers reached sea-level, is found from the earliest cold stage - the Praetiglian (2.6-2.4 my) and its equivalents, in the North Atlantic and North Pacific oceans. But traces of the early glaciations are limited, and it is difficult to reconstruct a picture of the extent of those early ice sheets.

Like the later Neogene, the Early Pleistocene (2.6–0.8 Ma) was characterised by climatic fluctuations dominated by the 41 ka precession cycle. It seems that until the transition in dominant orbital cyclicity to the 100 ka cycles that began ca 1.2 Ma and was fully established by about 800 ka, that the cold periods (glacials) are regularly not cold and long enough to allow ice-sheet development on a continental scale outside the polar regions. Here, MIS 22 (ca 880–870 ka) is the first of the 'major' cold events that reached critical d18O values of ca 5.5% or above equivalent to substantial ice volumes that typify glaciations of the Later Pleistocene (i.e. MIS 16, 12, 10, 6, 4–2). Potentially therefore, the most extensive (ca 5–6 periods) were limited to the last 900 ka. Precisely where these glaciations occurred and how far they extended is very difficult to determine, given that the remnants of early glaciations tend to be obliterated and mostly removed by later, more extensive advances. Especially in mountain regions, the preservation potential of older sequences rapidly diminishes with time and subsequent glaciation.

Beyond the glaciated regions of lowland Europe and elsewhere, flights of Quaternary river terraces provide an unrivalled record of drainage evolution and hydrological changes through the period. These terrace sequences share common characteristics involving low-gradient planed or irregular bedrock surfaces and single or multi-storey clastic deposits. Late Cenozoic environmental changes which affected European rivers, especially on those of mid-Pleistocene times (c.1.2–0.8 Ma or around MIS 22) and thereafter will be mentioned. These involved dominating but fluctuating cold-climate (periglacial) conditions, shorter but major episodes of glaciation, and brief interglacials. There were also related sea-level and tectonic responses. The known history of European rivers in this period is individually varied, but is predominantly marked by multiple stages of episodic incision the form of which changed in style at around the 'mid-Pleistocene transition'. It is suggested that the nature of climatic oscillations, the dating of incision episodes and the processes that achieve this incision are as yet insufficiently understood.

Pleistocene cyclostratigraphy

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Earth orbital parameters are precisely calculated for the last few Myr. They have a cyclic behavior in time that affects insolation at given latitude, thus the changes in the annual-mean insolation and more notably the difference between maximum and minimum insolation (seasonality) can be computed back in time.

When the effects of insolation changes can be recovered from the sedimentary record and correlated to the astronomical theory, they constitute an invaluable dating tool allowing a theoretical resolution of ¼ their period (or more practically ½ the period).

The effects of insolation changes in the sedimentary record are buried within other sources of variability that depends on the sediment characteristics and which can be considered as a disturbance (noise). Quite often, in the geological record, noise has a larger variability than the periodic signal that we are interested to detect, and statistical tools are required to disentangle them. Invariably these statistical methods assume that "noise" has a stochastic structure in time domain allowing separating it from the purely cyclic orbital signal. Non-linear response of the sedimentary records to the orbital pacing and phenomena such as deterministic chaos in the dynamics of sediment deposition can considerably complicate this task.

Cyclostratigraphic dating involves recognizing cycles and counting their number from a well-dated horizon such as present day or a geomagnetic reversal. Since individual cycles have a very little (if any) "peculiarity" a continuous record, with no hiatuses, is required. A rough idea of the time involved in the section is often also necessary.

Climatic control on palaeohydrology and sediment distribution in the Pleistocene deposits of the Guadix Basin (Betic Cordillera, Spain)

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The geological history of the Guadix Basin as an endhoreic depression occupying the central sector of the Betic Cordillera (S. Spain) spans since the Late Miocene to the Late Pleistocene. During that time interval, a master drainage system (Axial System) was responsible to carry water and sediment all along the basin axis from Sierra Nevada to the lake developed in the neighbouring Baza Basin. Transversally to this high sinuosity axial fluvial system, alluvial and fluvial fans developed lying against the basement rocks on the northern and southern basin´s margins.

The excellent quality of the outcrops and the accurate litho-, bio- and magnetostratigraphical control in the central sector of the basin has allowed us to identify an apparent cyclicity on the pattern of progradation of the transverse fans over the axial valley of ca. 100 ka, falling into the band of Milankovitch of high-frequency eccentricity.

The combination of the information provided by the facies and the stable isotope analyses (C and O) points out that the phases of progradation of the transverse fans would correspond to drier and possibly colder (glacial) conditions, with poor vegetation cover and water discharge concentrated in short periods. The widening of the axial floodplain overlapping distal fringes of the transverse fans, on the other hand, would coincide with wetter and warmer conditions (interglacial), with abundant rainfall and important subsequent development of vegetation cover to prevent erosion in source areas. The correlation to the astronomically tuned Global Polarity Time Scale of the sediments has allowed a tentative correlation of the transverse fan progradations to eccentricity minima peaks, while the intervals in which the axial valley would be occupied by the axial fluvial system might be correlated to eccentricity maxima peaks.

The precise knowledge of the palaeohydrological evolution of the sedimentary systems occupying the Guadix Basin makes this an excellent example to advance the understanding of the environmental transformations in southern Europe during Pleistocene times.

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Session 5: Biostratigraphy

L. Rook

The Early – Middle Pleistocene transition: the Italian large mammal record

J. Agustí

Biostratigraphic and climatic events in the early-middle Pleistocene transition of Eastern Spain

G. Cuenca-Bescós

The biostratigraphic position of the Lower Red Unit of the Sima del Elefante site (TELRU) based upon its small mammal assemblages (Atapuerca, Spain, Early Pleistocene), and the pre-Jaramillo faunas

J. van der Made

Large mammals and biostratigraphy around the Lower-Middle Pleistocene boundary and the Jaramillo in Europe

T. van Kolfschoten

Changes in the Central and Eastern European mammalian fauna during the mid-Pleistocene transition

B. Martínez-Navarro

The Epivillafranchian and the arrival of pigs into Europe

The Early – Middle Pleistocne transition: the Italian large mammal record

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Among vertebrate palaeontologists the Italian Pleistocene large mammal record (and particularly the mammal sites of the Upper Valdarno Basin, in Tuscany) is a reference one. The Upper Valdarno Basin is renowned for the occurrence of mammal fossil bones since Renaissance times, and fossil vertebrates from this Basin have been observed, collected, discussed, and kept in different private collections of early naturalists. Several mammal collections from the Italian celebrated fossiliferous sites are housed at various Museums and Institutes in Italy and over Europe. An historical overview on the Italian Early to Middle Pleistocene (Late Villafranchian to Galerian) large mammal faunas (and particularly for the mammal sites of the Upper Valdarno Basin) closely involves the ancient collections and the Museum that host the most important ones, the Florence palaeontological Museum, rooting his history in the granducal collections. The history of the Florence palaeontological museum and his collections has been recently published by Cioppi & Dominici (2011).

In more recent times, thanks to systematical re-evalutaion and new findings, fossil mammals representing the latest phase of the Villafanchian and the beginning of the Galerian Land Mammal Ages have been discussed in literature as important markers for defining the transition between the Early and the Middle Pleistocene. These are the sites located nearby the Romanesque Abbey of Farneta and at Selvella (two localities in the Chiana Valley, Tuscany), and the site of Pietrafitta (Umbria), Colle Curti (Colfiorito Basin, Marche), Madonna della Strada (Abruzzi), Capena (Latium), and Pirro Nord (Apulia). Throughout an overview of these local faunas, and of some selected large fossil mammal taxa, the Italian late Villafranchian / Galerian (Early to Middle Pleistocene) transition will be outlined in the frame of the European fossil record.

This contribution is dedicated to Prof. Augusto Azzaroli, in recognition of his fifty-year-long research activity on Plio-Pleistocene mammals, and to the memory to Claudio De Giuli (1938-1988) who disappeared 25 years ago, described some of the fauna subject of this talk, and inspired a number of students (one of them being the writer) to enter the field of Vertebrate Palaeontology.

Biostratigraphic and climatic events in the early-middle Pleistocene transition of Eastern Spain

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In this paper, a correlation is established between the main microvertebrate biostratigraphic events as recorded in a number of eastern Mediterranean Spanish continental sequences, and the climatic events between 1.4 Ma and 0.6 Ma. We include in this correlation the fluvio-lacustrine sequences of the Guadix-Baza Basin (SE Spain), Cal Guardiola (Vallès-Penedès), La Boella (Camp de Tarragona), as well as the karstic complexes of Almenara-Casablanca (Castellón) and Quibas (Murcia). According to this succession, a number of biozones have been recognized during this time-interval: *Allophaiomys ruffoi* Zone, *Allophaiomys* aff. *lavocati* Zone, *Victoriamys chalinei* Zone, *Iberomys huescarensis* Zone, *Stenocranius gregaloides* Zone and *Arvicola mosbachensis* Zone. According to the magnetostratigraphic correlation established in the Guadix-Baza Basin and other continental sequences, this set of biozones covers the upper part of the Matuyama subchron (inluding the Jaramillo subchron) up to the lower part of the Bruhnes chron. Along this sequence it is possible to recognize moments of dry and relatively cool climate, alternating with other moments of more humid and warmer conditions.

The biostratigraphic position of the Lower Red Unit of the Sima del Elefante site (TELRU) based upon its small mammal assemblages (Atapuerca, Spain, Early Pleistocene), and the pre-Jaramillo faunas

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Biostratigraphy underpin much of geoscience. No matter what aspect of geology and archaeology one is working on, the most common question posed by scholars is "what age is it?" Especially when dealing with fossil human remains.

Biostratigraphy provide the framework for answering that question. The aim of this work is to define and update the pre-Jaramillo small mammal faunas and its significance in the dating of the first fossil human, and its lithic industry remains in South-Western Europe.

The Sima del Elefante cave site (Sierra de Atapuerca), is extremely important in fossil, lithic artifacts, human and faunal remains. Why it is important? It is because the earliest record of human presence in Europe lies in the lower stratigraphic section or Lower Red Unit (TELRU) of the Sima del Elefante site, at level TE9. TELRU ranges from the bottom of the Sima del Elefante sequence (TE7) up to unit TE14 (TE7-TE14). Cosmogenic nuclide analysis provides an age of 1.2 Ma for level TE9.

The biostratigraphy provides a lengthier range: from the Plio/ Pleistocene boundary to the Matuyama-Jaramillo boundary. The small mammal assemblages of the TELRU have identical taxa from level TE7 to level TE14. Some taxa, such as *Asoriculus gibberodon*, *Castillomys*, and *Ungaromys* appear at the Pliocene/Pleistocene boundary while others, such as *Allophaiomys,* have their first appearance data at the end of the Olduvai magnetochron. The TELRU levels register their last known appearance data in Southwestern Europe. To give an example the *Allophaiomys* faunas are substituted in

Southern Europe by the *Microtus* faunas after the Jaramillo magnetic chron, as in the Gran Dolina Early Pleistocene (Atapuerca) levels. Other examples are in Italy, France, and Germany. Thus, the stratigraphic sequence of TELRU may be correlated by biostratigraphy in between the paleomagnetic events Olduvai/Matuyama and Matuyama/ CobbMountain or Matuyama/Jaramillo boundaries. Because the upper disappearance data of the majority of the small mammal species, which are recorded in TELRU, is before the Jaramillo event, we call these, the pre-Jaramillo faunas.

Concluding, given the increasing importance of the Jaramillo as a chronological landmark in Quaternary studies, our contribution here is the characterization of its lower boundary, by means of biostratigraphic events such as the last appearance data of several species of small mammals that had appeared at the beginning of the Pleistocene.

Large mammals and biostratigraphy around the Lower-Middle Pleistocene boundary and the Jaramillo in Europe

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In the context of this meeting, it is self-evident that the differences between faunas from the different chrons around the Jaramillo should be documented. The aim is to discriminate between the faunas from sediments with normal palaeomagnetism of the Jaramillo (chron C1r.1n) and Brunhes (C1n) and between the pre- and post- Jaramillo faunas (C1r.1r versus C1r.2r and earlier).

Cervus elaphus, Sus scrofa and *Crocuta crocuta* appeared in Europe during chron C1r.1r (eg. Atapuerca Gran Dolina, levels TD4-6, Dorn Dürkheim). Probably these species appeared well after the beginning of C1r.1r, but their presence precludes a pre-Jaramillo age. Similarly, the last appearance of *Leptobos* is pre-Jaramillo, its presence precluding a post-Jaramillo age. *Megantereon* last appeared in the Jaramillo. *Pachycrocuta* and *Panthera gombaszoegensis* are sometimes cited as typically Early Pleistocene, but the jaguar and, probably also, the giant hyaena reached the Middle Pleistocene, being thus irrelevant here.

Three different lineages of large deer evolved from pre-Jaramillo times into the Middle Pleistocene. The identification of the three lineages and their stages of evolution is delicate, but of great interest here.

Eucladoceros is a genus with gracile metapodials and first phalanges and branching antlers with the tines originating at the front of the main beam. A succession of species or subspecies covered the pre-Jaramillo to early Brunhes. Of particular interest is a large form present in Atapuerca TD4-8, Lakuthi, and several other localities, which is possibly typical of Cr.1r and the lowermost Brunhes.

Megaceroides (or *Praemegaceros*; included in *Megaloceros)* has robust metapodials and first phalanges and pedicles that have an enlarged transverse diameter. The lowermost tine is very close to the burr and frequently is reduced or absent. This tine and the next one have round sections. The different tines do not originate exactly at the front of the main beam and are not all in the same plane. In later forms, a distal palmation is developed. Different species of this lineage are present in the pre-Jaramillo and Brunhes. Unfortunately the timing of the transition is not precisely documented. The lineage is present in various levels and localities at Atapuerca.

Species of large deer with palmate brow tines are all placed in the genus *Megaloceros*. A pre-Jaramillo species has gracile metapodials and an antler with a high first bifurcation between brow tine and main beam and a distal branching pattern. This species seems to have given rise to two lineages with decreasing height of the first bifurcation. One of them became smaller and is known from the early Middle Pleistocene, as well as from the latest Early Pleistocene of Gran Dolina at Atapuerca. The other being large sized with robust metapodials appeared around the Brunhes-Matuyama transition and may have given rise to *Megaloceros giganteus*. Early representatives of this lineage are present in Cueva Victoria and Cueva Negra.

The rhinoceros species, which are of interest here, include a small form that either is seen as a late representative of *Stephanorhinus etruscus* or a form close to *Stephanorhinus hundsheimensis*. It seems to have been abundant in Spain, though it is known also from elsewhere, and ranges from the pre-Jaramillo till the beginning of the Middle Pleistocene (notably level TD8 at Atapuerca). A large form, which is currently attributed to *Stephanorhinus hundsheimensis*, is present in France and Germany from the Jaramillo onward (Vallonnet and Untermassfeld), but there does not seem to be a reliable record from Spain. As a consequence it is not clear whether the observed distribution pattern of these two species is mainly temporal or mainly geographical. *Stephanorhinus hemitoechus* (cited from Solana del Zamborino) appeared during the later half of the Middle Pleistocene.

Changes in *Alces*, *Bison* and *Soergelia* will also be discussed, while changes in *Mammuthus* are well known and are omitted here.

Changes in the Central and Eastern European mammalian fauna during the mid-Pleistocene transition

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The end of the Early Pleistocene is an exciting period particularly for mammalian palaeontologists. In Eurasia, this interval shows a faunal turnover caused by both the evolution and migration of species. It is the time in which the famous end-Villafranchian 'event' takes place, a phenomenon that is characterized by a faunal turnover resulting mainly from the migration of larger mammals. The smaller mammal record reveals in particular an important radiation in medium-sized voles. Different *Microtus* species evolve rapidly from species of the genus *Allophaiomys,* and various lineages can be observed. This radiation finally leads to the present-day diversity in the smaller mammals.

In Eastern Europe, particularly on the Russian Plain and the Taman Peninsula, there are a number of localities where faunal assemblages from well-dated stratigraphical sequences can be studied. These assemblages show the mid-Pleistocene evolution of rodent faunas within Eastern Europe. Identical and synchronous changes in the mammalian faunas are found in other parts of Europe.

The Epivillafranchian and the arrival of pigs into Europe

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The lack of record of a taxon in a fossil faunal assemblage is not an evidence of its absence from the original paleocommunity. However, the non-appearance of suids in Europe at any of the Late Villafranchian sites with chronologies between 1.8 and 1.3-1.2 Ma, such as Dmanisi (Georgia), Apollonia 1 (Greece), Argentario and Pirro Nord (Italy), Sainzelles (France), or the Spanish sites of Orce (Venta Micena, Fuente Nueva-3, and Barranco León) and Incarcal, is a strong argument that should not be avoided, as the presence or absence of pigs is most probably a reliable biochronological marker for the European continent.

Suids are found in Europe before and during the Olduvai subchron, including the Fonelas P-1 site in the Guadix Basin, dated to 2.0 Ma, which suid remains have been ascribed to *Potamochoerus magnus* (Arribas et al., 2009), and many other localities with the presence of *Sus strozzii* (for review, see Rook and Martínez-Navarro, 2010). However, there are no pigs in the chronological range comprised between the post Tasso Faunal Unit, in the base of the Late Villafranchian (~1.8 Ma), and their arrival in Western Europe at layer TE9 from Sima del Elefante (~1.2 Ma), where pigs are recorded under the name of *Sus* sp. (Carbonell et al., 2008), and at the site of Untermassfeld (Germany), dated 1.0-1.1 Ma, which suid remains have been ascribed *to Sus scrofa priscus* (Gúerin and Faure, 1997). Later, the genus *Sus* is recorded everywhere in Europe as an ubiquitous member of the Evillafranchian/Galerian and posterior faunas.

When pigs are in the ecosystem, they use to be abundant in the large mammal community given their opportunistic feeding behavior and reproductive success. Suids are ungulates that follow a *r*-selection reproductive strategy, with elevated offspring numbers. This means that their capability of reproduction allows them to colonize new and varied environments and territories with much more speed than other ungulates, which use to display a *K*-reproductive strategy, with a single pup per birth. For this reason, suids are usually abundantly preserved in the fossil assemblages.

Suid remains are well represented in the African and Asian archaeological and paleontological sites, including those from the Levantine Corridor as 'Ubeidiya, but they are not definitively present in the European continent during the period comprised between 1.8 and 1.2 Ma.

The arrival of suids into the European continent marks the beginning of the Epivillafranchian and the end of the Late Villafranchian, which is aproximately dated at ~1.1 Ma (see Rook and Martínez-Navarro, 2010). Also, suids are omnivorous generalistic species with bunodont teeth, which do not tolerate very low temperatures, showing that their colonization of Europe can be related to a change in the ecosystems and climate. In any case, the arrival of suids postdates the earliest arrival of the first hominins into Europe, an event recorded at the Orce and Atapuerca sites with chronologies close to 1.4 Ma (Bermúdez de Castro et al., 2013; Espigares et al., 2013; Toro et al., 2013).

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<u>Session 6: Human evolution / Archaeology</u>

J.M. Bermúdez de Castro

Continuity versus discontinuity of the Early Pleistocene European human populations: The Atapuerca evidence

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Plio-Pleistocene Archaeology of Gona Study Area, Afar, Ethiopia

Continuity versus discontinuity of the Early Pleistocene European human populations: The Atapuerca evidence

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During the last decades, we have witnessed a significant increase in the number of evidences in favour of the human settlement of Europe during the Early Pleistocene. However, there are still many issues open about the character of this occupation such as whether Europe was continuously populated or not since the first hominins arrived to the continent. Increasing climatic oscillations and seasonality as well as some palaeogeographic factors may have conditioned the pattern of colonization of Europe.

The Gran Dolina (TD) and Sima del Elefante (TE) cave sites in the Sierra de Atapuerca, (Spain) include large and quasi-continuous stratigraphic sequences that stretch back from at least 1.2 million years ago (Ma) to the Matuyama/Brunhes boundary. The archaeological and paleontological record from these sites can help to test different hypotheses about the character of the human settlement in this region and period. A fragmentary human mandible, dated to about 1.2 million years ago, was recovered from the TE9 level form the TE cave site. Furthermore, the TD6 level has yielded a large collection of human fossil remains attributed to *Homo antecessor*. According to different geochronological methods, as well as to paleomagnetic and biostratigraphical analyses, these hominins belong to an age range of 0.96 to 0.80 Ma. Unfortunately, the comparison of these two hypodigms is not enough to conclude whether the Gran Dolina-TD6 hominins and the Sima del Elefante human remains represent the same species, although large departures from the African morphologies can be ascertained in both samples. A set of derived features of *H. antecessor* shared with both the Neanderthal lineage and modern humans suggests that this species is related, and not far, from the most recent common ancestor (MRCA) of *H. neanderthalensis* and *H. sapiens*. Having into account these observations, if we assume that there was a lineal biological relationship between the TE9 and TD6 hominins, we should reconsider many of the conclusions achieved in previous paleontological and genetic studies. In addition, we would be obliged to build a highly complicated paleogeographical scenario for the origin of the MRCA. Although continuity in the settlement of Europe during the entire late Early Pleistocene is not discarded (e.g. in refuge areas), it seems that this Western extreme of Eurasia, and the Iberian Peninsula in particular, was occupied by at least two different hominin populations.

The Early Human Colonization of Europe: A view from the North

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The pre-glacial 'Crag Basin' of eastern England is a rich source of Early and early Middle Pleistocene fossils and Lower Palaeolithic sites. Buried beneath a complex sequence of till and glacial outwash are extensive sheets of shallow marine sediments (known locally as 'Crags') and a fluvial/alluvial sequence (the Cromer Forest-bed Formation, CF-bF), deposited along the southern margin of the subsiding North Sea Basin (Gibbard *et al*., 1998; Preece and Parfitt, 2012). In East Anglia, these deposits occupy an area of ~42, 000 km^2 in parts of Norfolk and Suffolk, where they are locally more than 50 m thick. Correlation with even deeper sequences in the North Sea and The Netherlands (Hijma *et al*., 2012) has been established on the basis of mammals, molluscs, Foraminifera, ostracods, dinoflagellates and pollen. The presence of both marine and terrestrial fossils in these sediments allows an unusually complete reconstruction of climatic and environmental change in north-western Europe, spanning the late Pliocene to the early Middle Pleistocene.

Following the discovery of Lower Palaeolithic artefacts at two coastal exposures at Pakefield (Parfitt *et al*. 2005) and Happisburgh (Parfitt *et al*. 2010), fieldwork since 2000 has identified a further six distinct Lower Palaeolithic sites associated with Crag Basin sediments. These sites are of exceptional interest due to the wealth of associated organic remains (including beetles, vertebrates, molluscs, pollen, plant macrofossils, ostracods) that offer an unparalleled opportunity to investigate the general climatic and environmental setting of early humans at the northern edge of their range during the Early and early Middle Pleistocene.

The earliest stone tools at Pakefield (~ 700 ka) and Happisburgh 3 (~800, 000 – 900, 000 ka) are typical of core and flake technologies (Mode 1) known elsewhere in Europe at this time. In Britain, the adoption of a more advanced Acheulean technology (Mode 2) occurs towards the end of the early Middle Pleistocene at around 500 ka, and is exemplified by the handaxe from Happisburgh 1. The sites are all located in close proximity to large rivers, but occupation occurred under markedly contrasting climatic and environmental conditions. At Pakefield, humans were present during the peak of the interglacial in a landscape dominated by regional deciduous woodland, whereas at

Happisburgh 3, the stone tools are associated with mixed woodland and a climatic regime analogous to southern Scandinavia at the present day.

This talk will outline results from recent archaeological excavations along the East Anglian coast and their implications for understanding the earliest human colonization of northern Europe. The unexpected discovery of artefacts in the CF-bF after nearly 200 years of intensive investigation raises important issues regarding sampling and the recognition of hominin presence from modified bones and stones. The 'Eolith Debate' which focussed archaeological interest on the 'Crags' and 'Forest Bed' during the late 19th and early 20th centuries (O'Connor, 2007) is not a dead issue, but has resonance today with claims for an even earlier (~1 Ma, Jaramillo subchron) incursion of humans into northern Europe based on apparent artefacts and modified bones from central Germany (Garcia *et al*., 2013).

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The Pirro Nord site (Apricena, FG, Southern Italy) in the context of the first European peopling: convergences and divergences

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Pirro Nord, located in Apricena in Southern Italy, represents one of the first evidences of human dispersal in Europe. The site is dated on biochronological bases between 1.3 and 1.6 My and a significant vertebrate assemblage (Pirro Nord Faunal Unit) is associated with lithic artefacts that show numerous similarities with more or less contemporaneous lithic assemblages in Europe and with the African Mode 1 (Arzarello *et al.*, 2012; 2007).

Pirro Nord is a karst fissure situated in a stratigraphic boundary between the Mesozoic limestone and the Pleistocene calcarenite located at the top of the sequence. This fissure was filled by a skeleton of large blocks and by a sandy-clayey sediment.

The vertebrate assemblage is dominated by a large number of carnivores and ungulates; it includes also 20 species of amphibians and reptiles and more than 40 species of birds.

The reduction sequences are always exploiting local flint (collected as small and medium size cobbles) very short. The knapping strategies are strongly influenced by the initial morphology/dimensions of the raw material.

The main objective of production is the manufacture of flakes with at least one functional edge by an opportunistic or (more rarely) centripetal method, as highlighted also in others European sites with a similar chronology.

Even though the site is well situated in the context of the first European peopling, from a point of view of adopted debitage methods, a morphometric analysis applied to a specific component (debordant centripetal flakes) has allowed to highlight a strong concept of predetermination.

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Palaeoecology of mammals as a factor in the distribution of *Homo* at the end of the Early Pleistocene

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The Early-Middle Pleistocene transition is a key period in the human settlement of Europe and it is also a time of relevant faunal renewal and ecological change. Evidence of human presence in Europe is scarce before 1.2 Ma and it is restricted to the Mediterranean region. However, the number of sites with fossil or cultural hominin remains dated to the 1.2 to 0.8 Ma. time interval is markedly higher. In addition, in this period humans were able to cross parallel 45º N for the first time. In contrast, the number of sites dated to the early Middle Pleistocene (0.8-0.5 Ma.) is again low. The 1.2-0.8 Ma. period corresponds to the early Galerian or Epivillafrachian large Mammal Age, a time when a marked reorganization of the European large mammal communities occurred. The distribution of mammal species at both sides of parallel 45º N was more even in the early Galerian than in the former age, the late Villafranchian. The ecological structures of the northern and southern regional mammalian species pools were also more similar in the early Galerian than in the late Villafrachian (Rodríguez et al., 2013). Although ecological differences between Mediterranean Europe on the one side and Central and Northern Europe on the other persisted, the homogenization of the fauna suggests that those differences were smaller in the early Galerian than before. The early Galerian faunal change specially affected the composition of the large herbivore and carnivore guilds, promoting a significant modification of the trophic relationships in mammalian communities (Rodríguez et al., 2012). The body size of herbivore species increased in comparison to the late Villafranchian, resulting in faunas with an extremely high proportion of megaherbivores. Body size is the main defense of mammalian prey against their predators. Thus, the increase in average body size of the primary consumers, joined to a decreased number of predators able to kill them, produced faunas that included several predator-free species. Somewhat paradoxically, the concomitant loss of diversity of the carnivore guild resulted in a diminished intraguild competition in comparison to the late Villafranchian. In summary, hominins likely entered Europe during the late Villafranchian, when competition inside the carnivore guild was high and the ecological barrier separating northern from southern Europe was relatively low. This scenario changed in the early Galerian with a less diverse carnivore guild, reduced intraguild competition and a more homogeneous distribution of the fauna across a north-south gradient.

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Hominid settlements in the Maghreb during the Early and Middle Pleistocene

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The early part of the Plio-Pleistocene in North Africa is characterized by hominid settlements currently limited only to the Ain Hanech sites in northeastern Algeria. The Ain Hanech archaeological evidence shows that hominid presence in North Africa dates back to roughly between 2.0 and 1.7 million years ago (Ma), and the earliest artifact tradition was the Oldowan. In addition, the upper Ain Hanech deposits possibly contain the earliest Acheulean in this part of the African continent. While the chronological transition from the Oldowan to the Acheulean is barely present, the Maghreb documents a continuous archaeological record witnessing a thriving development of the Acheulean tradition during the period from 1.0 Ma to 0.4 Ma (a period roughly contained within the Early-Middle Pleistocene transition [1.2-0.5Ma]). Although the Acheulean material is widespread all across the Maghreb, the major sites include the Casablanca area on Atlantic Morocco and Tighennif (formerly Ternifine) on the Algerian western High Plateaus. The Acheulean in the Maghreb embodies several stages of developments exhibiting technological innovations and a continuous progress of the morphology of the artifacts with more precision on thinning and shaping bifaces with a well-defined symmetry, and predetermined flaking techniques for manufacturing standardized artifacts. Paleoecologically, settlement activities took place in both riverine and lacustrine environments, supporting open and arid savannah habitats, usually in areas where there is a permanent body of water. In spite of the open and dry habitat, meat probably constituted a major part of the Acheulean diet as indicated by the presence of hominid-inflicted butchery marks on fossil animal bones. With the discovery, primarily in Tighennif and in the Casablanca sites, the hominids responsible for the Acheulean activities may form two groups: early *Homo erectus* (or *H. ergaster*) and late *H. erectus* from which modern humans have emerged. Thus, the archaeological evidence from the Maghreb contributes significantly to a better understanding of hominid adaptations to the Mediterranean ecology during the Early and Middle Pleistocene.

Plio-Pleistocene Archaeology of Gona Study Area, Afar, Ethiopia

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Gona is a palaeoanthropological study area located in the Afar region of Ethiopia. It is well-known for yielding the oldest stone artifacts in the world dated to 2.6 million years ago (Ma). The earliest stone technology, referred to as the "Oldowan," lasted for about one million years (2.6-~1.7 Ma) - with the Acheulian, a new stone industry, making debut in East Africa by ~1.76 Ma. Currently, the earliest Acheulian is documented at Kokiselei in Kenya, and at Konso in Ethiopia. Four archaeological sites, DAN-5, BSN-12, BSN -17 and OGS-12 from Gona, Ethiopia, have also yielded among the earliest Acheulian artifacts dated to ~1.7-1.6. Extensive field survey and excavations at these sites have resulted in the discovery of stone artifacts which consist of 'large cutting tools' including unifacially and bifacially shaped crude handaxes and picks, as well as Mode I (Oldowan) cores, and débitage. The emergence of the Acheulian coincides with the appearance of early *Homo erectus/ergaster*, a large-brained hominin responsible for crafting purposefully-shaped large cutting tools that are unknown during the preceding Oldowan (2.6-1.76 Ma). However, our understanding of the Oldowan – Acheulian transition is still very limited.

Although the archaeological record between 1.5-0.5 is sparse at Gona, DAN16, a site estimated to ~1.2 Ma has yielded stone artifacts of Oldowan character. The age of the site is estimated based on a paleomagnetic transition documented below the site identified as the Jaramillo event. By about ~0.5-0.3 Ma, the archaeological record at Gona shows an inception of the Middle Stone Age, a new stone tool tradition characterized by prepared stone technology. Despite abundant archaeological materials, very little is known about the makers of this stone technology in Africa.

In addition to the wealth of archaeology, Gona has also produced more than 50 hominin fossils documented within key time intervals. The Gona deposits span the last six million years, and the hominin discoveries include *Ar. kadabba* (~5.8 Ma), *Ar. ramidus* (~4.5 Ma), and early and later *Homo erectus* (~1.6 and ~0.5-0.3 Ma respectively).

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EARTHTIME – EU Objectives

This Research Network Programme (RNP) proposal is part of a broader international initiative "EARTHTIME: a community-based scientific effort aimed at sequencing Earth history through an integrated geochronologic and stratigraphic approach". The ambition is to broaden the EARTHTIME platform in Europe with this RNP, which combined with a proposed FP7 Marie-Curie Initial Training Network ("GTSnext"), will also serve as the basis for wider outreach towards the Earth Science community, and allow crucial construction of databases and teaching activities with a global dimension.

The Geological Time Scale (GTS) is the fundamental measurement yardstick and the key to reconstruct Earth history. We want to (1) develop a next generation fully integrated GTS for the last 100 million years, and (2) exploit the scientific predictions arising from this improvement. This time scale, with unprecedented accuracy, precision, resolution and stability, can be achieved by integrating independent dating techniques. The numerical calibration of the GTS is the main focus of the GTSnext-ITN. With the RNP we specifically aim to link the much improved numerically calibrated time scale with other stratigraphic disciplines to arrive at a fully integrated GTS.

Combining the RNP with GTSnext, the expected scientific contributions and breakthroughs are 1) new insights into key geological processes including climate change, catastrophic impacts, and volcanic hazards, 2) a stable time scale that is beneficial for academia and industry, 3) full integration and intercalibration of different numerical dating and stratigraphic techniques, leading to 4) significant improvement in the consistency of these techniques; 5) progress towards a fully astronomically-tuned and stratigraphically integrated GTS over the last 100 million years.

A fundamental comprehension of geological time and the time scales at which key processes occur is appropriate in view of the impact we have on System Earth. The website for the EARTHTIME-EU contribution is http://earthtime-eu.eu/earthtime/http://www.earthtime-eu.eu.

The running period of the ESF EARTHTIME-EU Research Networking Programme is for 5 years from June 2010 to May 2015.

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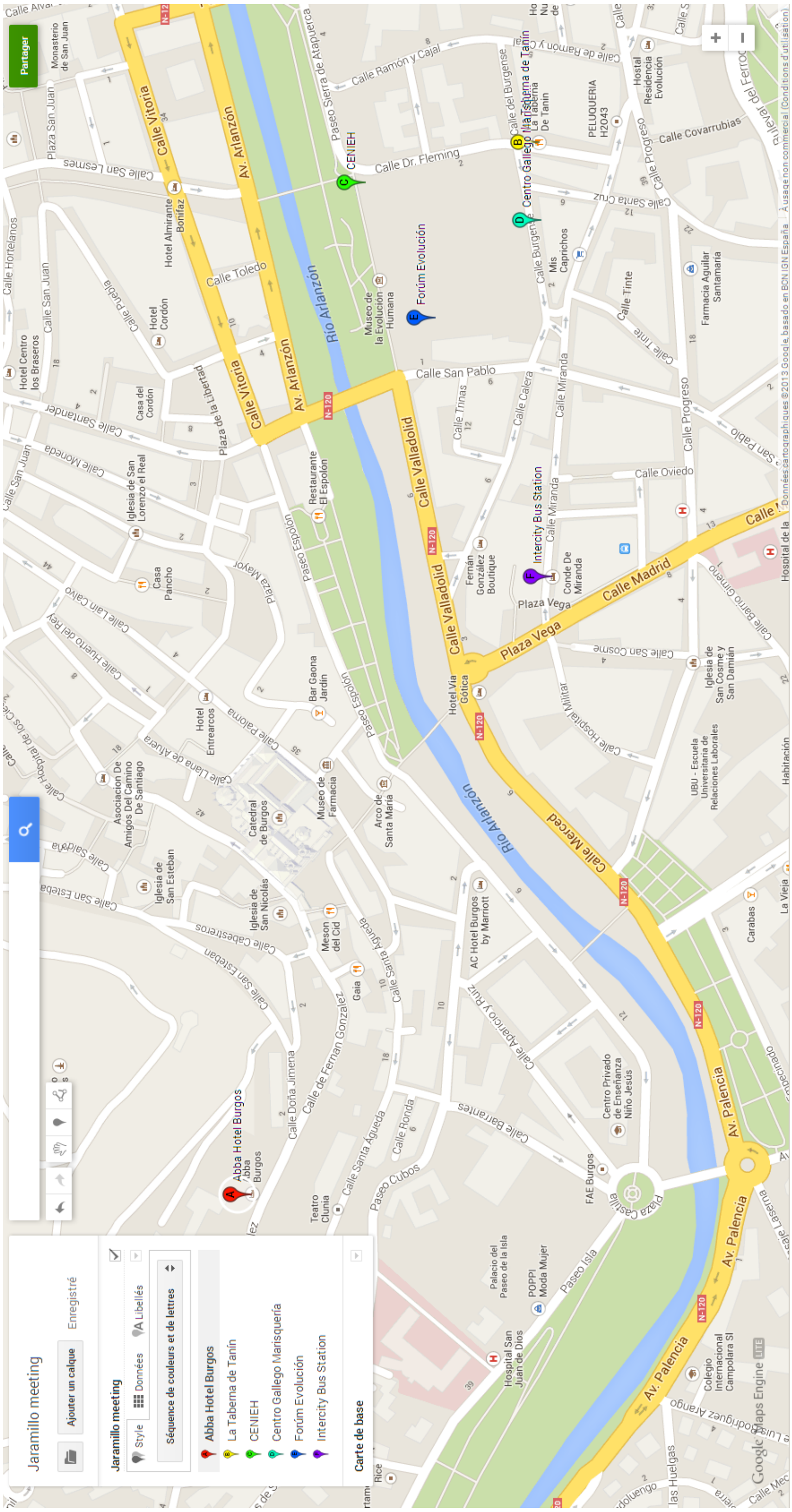
Jaramillo meeting
Abba Hotel Burgos
La Taberna de Tanín
CENIEH
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