Paleogene events, Evolution and Stratigraphy

The Alano section: the candidate GSSP for the Priabonian Stage

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The deep water hemipelagic Alano section, located in the Southern Alps of northern-eastern Italy close to the village of Alano di Piave in the type area of the Priabonian, has been presented since 2005 as the potential Global Boundary Stratotype Section and Point (GSSP) for the late Eocene Priabonian Stage at several meetings of the International Subcommission on Paleogene Stratigraphy (ISPS). Because of the good qualities of the section we have been asked to produce the data necessary for the formal definition of the GSSP. In 2011, AGNINI *et al.* published most of the documentation needed (lithostratigraphy, calcareous plankton biostratigraphy, magnetostratigraphy and chemostratigraphy, including oxygen and carbon isotopes and carbonate content). The latter paper also contained a motivated proposal for the definition of the Priabonian at the base of a prominent crystal tuff layer, the Tiziano bed, located at 63.57 m level in the Alano section. Following the publication of this proposal an unanimous consensus on the Alano section as the GSSP of the Priabonian (i.e., GRADSTEIN *et al.*, 2012; WADE *et al.*, 2012) has been reached during an *ad hoc* workshop held in Alano in June 2012. However, not unexpectedly, alternative criteria for the definition of the GSSP have been later advanced (GRADSTEIN *et al.*, 2012; WADE *et al.*, 2012; LESS & ÖZCAN., 2012). In 2012, we have further refined the stratigraphy of the Alano section by obtaining cyclostratigraphic data. Moreover U-Pb dating of zircons from seven levels has been undertaken. Here, we present the new available cyclostratigraphic data and discuss various proposals for the definition of the Priabonian at Alano, and finally reiterate that our original proposal is the most balanced and in a better keeping with Hedberg's principles of chronostratigraphy.

Keywords: Chronostratigraphy, Paleogene, Eocene, Priabonian, Alano section, GSSP.

Differential effects of bioturbation on benthic foraminiferal distribution across the Cretaceous/Paleogene (K/Pg) boundary at Bidart (SW France)

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In order to assess the role of tracemakers in the reworking of benthic foraminifera across the Cretaceous/Paleogene (K/Pg) interval, we studied benthic foraminifera present in the material infilling trace fossils (*Planolites, Thalassinoides* and *Zoophycos*) and in the surrounding sediment observed in the uppermost

Maastrichtian in the Bidart section (SW France). Deposition took place in the upper part of the slope during the uppermost Cretaceous and lower Danian at Bidart, as inferred from benthic foraminifera from the background sediment (not affected by burrows). Our results support the significance of tracemakers for reworking benthic foraminiferal assemblages, as previously suggested by calcareous nannofossils assemblages.

Keywords: Bioturbation, Cretaceous/Paleogene interval, Benthic Foraminifera.

Benthic foraminifera, food supply and carbonate saturation across the Cretaceous/Paleogene boundary: Southern Ocean Site 690

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The specific mechanisms causing extinction and faunal turnover after the impact of an asteroid at the Cretaceous/Paleogene (K/Pg) boundary, and the palaeogeographical variability of the biotic response, are not well understood. In order to evaluate causes of extinction and compare the biotic turnover of deep-sea benthic foraminifera at high southern latitudes with that at globally distributed sites, we analysed benthic foraminiferal assemblages at Southern Ocean ODP Site 690 on Maud Rise, Antarctica. Proxies for export productivity and the species composition of benthic assemblages indicate that the food supply to the seafloor did not change significantly, but diversity and evenness decreased for several 100 kyrs. This transient assemblage change may have been caused by the extinction of pelagic calcifiers, either directly because of the changed nature of the organic flux, or indirectly, because the sharp decline in pelagic carbonate flux to the deep-sea floor caused carbonate oversaturation of deep waters, leading to increased abundance of large, thick-walled and heavily calcified species.

Keywords: Cretaceous/Paleogene interval, Benthic foraminifera, Pelagic calcifiers.

Paleogene carbonates of Oman: Lithofacies and Stratigraphy

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Limestones deposited on the SE Arabian shelf during Paleogene time were studied from surface and subsurface in North and South Oman with focus on lithofacies, biota distribution and depositional paleoenvironment related to stratigraphy. The facies associations and benthic biota distributions can be differentiated according the time-slices Late Paleocene/Early Eocene, Middle Eocene and Oligocene. Arabian platform development and regional controls for the distribution of facies and biota are discussed.

Keywords: Paleocene/Eocene, Oligocene, limestones, carbonates, palaeo-environment, biotic changes, surface and subsurface, Arabian platform, Oman.

Integrated stratigraphy (magneto-, bio- and chronostratigraphy) and geochronology of the Paleogene pelagic succession of the Umbria–Marche Basin (central Italy)

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Extensive outcrops in the Umbria–Marche Basin of central Italy include some of the most complete successions of Paleogene sediments known from the Tethyan Realm. Owing to the continuous deposition in a pelagic setting, a rather modest tectonic overprint, the availability of excellent age control through magneto-, bio-, chemo- and tephrostratigraphy, and direct radioisotopic dates from interbedded volcaniclastic layers, these sediments have played a prominent role in the establishment of standard Palaeogene time scales. We present here a complete and well-preserved Paleogene pelagic composite succession of the Umbria–Marche Basin, which provides the means for an accurate and precise calibration of the Paleogene time scale. As a necessary step towards the compilation of a more robust database on a wide scale so as to improve the magneto-, bio- and chronostratigraphic framework of the classical southern Tethyan zonations, enabling regional and supraregional correlations, we have constructed a record of reliable Paleogene planktonic foraminiferal, calcareous nannofossil and dinocyst biohorizons commonly used in tropical to subtropical Cenozoic zonations. An age model is provided for the Paleogene pelagic composite succession of the Umbria-Marche Basin based on magnetostratigraphy, planktonic foraminifera and calcareous nannofossils, which contributes to an integrated chronology for the Paleogene Tethyan sediments from 66 to 23 Ma. Ultimately, the temporally closely constrained biohorizons provided by our study may provide an improved basis for regional and supraregional correlations and contribute to an improved understanding of the palaeoclimatic and palaeooceanographic dynamics of the Palaeogene world.

Keywords: Integrated stratigraphy, geochronology, Paleogene, Umbria-Marche Basin, Italy.

Integrated stratigraphy of the Monte Cagnero pelagic sequence in the Umbria-Marche basin (northeastern Apennines, Italy): A potential candidate for defining the Global Stratotype Section and Point (GSSP) for the Rupelian/Chattian boundary

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The pelagic succession of the Umbria-Marche Apennines (central Italy) includes a complete and continuous sequence of marly limestones, calcareous marls and marls with some intercalations of datable volcaniclastic layers that enabled the Oligocene Integrated Stratigraphy (OLIS) Working Group to construct an integrated stratigraphic framework for this Epoch. We present here a synthesis of a detailed biostratigraphic, magnetostratigraphic, and chemostratigraphic study of the Monte Cagnero (MCA) section, which accurately records calcareous plankton and dinoflagellate cyst biozones, magnetic reversals, seawater Sr, C and O isotopic variations, along with geochronologic results from several intercalated biotite-rich volcaniclastic layers, which provide the means for an accurate and precise radiometric calibration of the Oligocene Epoch, and a reassessment of the accuracy of existing geochronologic time scales. The interpolated radioisotopic age for the Rupelian/Chattian stage boundary, located in the upper half of Chron C10n at meter level 189, and corresponding to the O4/O5 planktonic foraminiferal zonal boundary, is 28.27±0.1 Ma. The accessible, complete, and continuous Monte Cagnero section, rich in well-preserved planktonic foraminifera, calcareous nannofossils and dinoflagellate cysts, is here presented as a potential candidate for defining the Global Stratotype Section and Point (GSSP) for the late Oligocene Chattian Stage. Work is in progress on establishing an astrochronological calibration of the Monte Cagnero section based on orbital tuning of high-resolution magnetic susceptibility and calcium carbonate data series. The proposed GSSP of Monte Cagnero bears all the stratigraphic and geochronologic attributes for driving the "golden spike", which define the Rupelian/Chattian boundary according to the International Union of Geological Sciences (IUGS) recommendations.

Keywords: Integrated stratigraphy, GSSP, Rupelian/Chattian boundary, Umbria-Marche Basin, Italy.

Atlas of Paleocene shallow larger benthic foraminifera
An introductory note

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A wealth of data on the morphology, biostratigraphy, and paleogeography of Paleogene larger benthic foraminifera (LBF) is available. The taxonomic and stratigraphic revision of the most diverse groups of LBFs (nummulitids, alveolinids, orthophragmines) in the 1970-1980 produced the Tethyan SBZ (Shallow Benthics Zonation) zonation. Recent developments in systematics, isotopic geochemistry, structural analysis of the complex tests, biostratigraphic interpretation of shallow marine sediments, Cenozoic paleogeography and paleoclimate in particular, need to be presented in a way that everyone may easily get up to date information about the species of this particular group of microfossils. In order to obtain full appreciation of recent progress, a group of micropaleontologists (the Working group on Larger Foraminifera, WOLF) working on Paleogene larger foraminifera decided that an useful means for integrating diverse data is to produce atlases. Traditionally, atlases are considered as the most useful tool for the field geologists, regional stratigraphers and paleontologists. Through several meetings (Ankara 2009, Miskolc 2010, Croatia 2011, Austria and Slovenia 2012), guidelines for the atlases, including a time-line, have been defined. The updated taxonomy, paleoecology and biostratigraphy of the diverse Paleogene larger foraminifera (including over 1150 recorded species) will be thus presented through atlases. It is planned to overcome discrepancies in quantity and quality of data between the Central Tethys area (for which monographs exist since the late 19th century, and more recently from Turkey and the Northern Peritethys) and the Middle-, Far East Tethyan and Caribbean bioprovinces, by a) a revision of museum collections; b) inviting micropaleontologists from these regions to join in this collaborative effort.
The first stage is an Atlas of Paleocene larger benthic foraminifera, where each species-rank taxon (at least 153 known) will be described with original or emended species descriptions, synonymy, biostratigraphic range information (the SBZ biozonation), paleoenvironmental interpretation, illustrated with original and new images, including the holotype, and whenever possible, with SEM and CT-Scan3D images.

Keywords: Atlas, Larger benthic foraminifera, Paleogene, Paleocene.

A revised Paleocene (Teurian) dinoflagellate cyst zonation from eastern New Zealand

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Organic-walled dinoflagellate cyst (dinocyst) assemblages are documented from Paleocene (New Zealand Teurian Stage) sediments in five sections from eastern New Zealand: Tawanui, Angora Road and Toi Flat-1 core in the East Coast Basin, mid-Waipara River in the Canterbury Basin, and ODP Site 1121 on the eastern margin of Campbell Plateau. Based on dinocyst results from these sections, along with published earliest Paleocene records from the East Coast, Canterbury and Great South Basins, a revised Paleocene dinocyst zonation is proposed. The interval zones are labelled as NZDP – New Zealand Dinocyst Paleocene – and the eight zones, NZDP1 to NZDP8, encompass the entire Paleocene, from 66.04 Ma to 55.96 Ma. Correlation of the NZDP zones with the International and New Zealand Time Scales is provided, and is primarily based on correlation with calcareous nannofossil biostratigraphy.

Keywords: Dinoflagellate cyst, Paleocene, Teurian, New Zealand, Zonation

In search of the Bartonian (Middle Eocene) GSSP (II): Preliminary results from the Oyambre section (N Spain)

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The Global Stratotype Section and Point (GSSP) for the base of the Bartonian (middle Eocene) stage is as yet undefined. Herein the potential of the La Acebosa Formation exposed on the eastern side of the Cape of Oyambre (San Vicente de la Barquera, province of Cantabria, N Spain) is analysed. Sedimentological and benthic foraminiferal data indicate that the La Acebosa Formation represents a bathyal environment related to a deepening, eastward-facing slope. Preliminary planktic foraminiferal and calcareous nannofossil results show that the upper part of the section corresponds to zones E11 and CP14a, respectively, and thus could include the Lutetian/Bartonian boundary. Although demagnetization quality is quite poor, preliminary magnestostratigraphic data suggest that Chron C19n, which is most likely to define the Bartonian GSSP, could be recorded in the upper part of the La Acebosa Formation. A denser magnetostratigraphic and biostratigraphic sampling is required in the upper part of this unit in order to accurately identify Chron C19n and establish the sequence of events across the Lutetian/Bartonian transition.

Keywords: Eocene, Bartonian, GSSP, Pyrenees, Cantabria, Oyambre.

Early Eocene Cerithioidean gastropods in a subtropical coast (South Pyrenees, Spain)

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The biodiversity of Eocene cerithioidean gastropods from a subtropical marine littoral environment, including mangroves with Nypa palms, is documented from the Figols group (FG) and the overlying Castigaleu group (CG), of the Ager and the Tremp-Graus Basins (south-central Pyrenees, Spain). The stratigraphic interval includes the middle and upper Ypresian, encompassing the early Eocene climatic optimum (EECO). The malacofauna comprises a rich association of possibly intertidal species, dominated by Potamidiidae, Batillariidae, Pachychilidae and Cerithiidae, with subordinate Melanopsidae, Thiaridae, Diastomidae and Pachymelaniidae. The subtidal fauna is dominated by Turritellidae. The Cerithioidea fossil distribution is interpreted according to their local paleoenvironmental gradients and through their genus-level stratigraphic distributions and according to known molecular phylogeny, ecology and geographic range of Recent forms. The cerithioidean record during the Paleogene is revised on a global scale to get an insight in the evolution across the EECO of some of the most widespread intertidal tropical organisms. The study suggests that Potamididae were adapted to mangrove trees since their first important diversification in Western Tethys and that some early Eocene genera survive in Recent mangrove-fringed coasts. Also the Batillariidae are very abundant and widespread in intertidal assemblages, undergoing rapid early Eocene turnovers, but within genera unrelated to modern forms. EECO Pachychilidae lived in brackish water habitats, contrary to purely freshwater Recent species. Turritellidae display an environmental distribution in the early Eocene similar to their modern distribution.

Keywords: Paleogene, Ypresian, Cerithioidea, shallow marine, ecological gradient, evolutionary diversification.

Identification of the Paleocene -Eocene boundary based on larger foraminifers on the Paleogene Adriatic carbonate platform (PgAdCP) (sections Sopada, Vrhpolje, SW Slovenia)

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Two sections placed on the NW part of the Paleogene Adriatic carbonate platform (PgAdCP) were measured and sampled in order to document the complexity of changes at the Paleocene-Eocene boundary. Carbon and oxygen isotope records in combination with detailed study of larger benthic foraminifera (LBF) are used to describe foraminiferal turnover in order to refine Shallow Benthic Zonation scheme.

Keywords: Paleocene/Eocene boundary, Larger benthic foraminifera, SBZ 4-6, Carbon isotope, Adriatic carbonate platform.

Paleocene siliceous sediments in the SW-Pacific

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Quantitative analysis of the acid-insoluble residue of the late Paleocene sediments of ODP Site 1121B, located at the foot of the Campbell Plateau in the SW-Pacific, reveals a 30m long interval, in which siliceous microfossils are relatively well preserved.
Correlation with results from analysis of the stable carbon- and oxygen isotopes from the same site shows that this abundance maximum in siliceous microfossils and the interval, in which they are best preserved, coincides with the late Paleocene productivity maximum.
Taxonomic analysis of the diatoms suggests dominance a) of species indicating high productivity and b) of heavily silicified neritic species, but an absence of freshwater species and benthic species. The abundance of neritic species in these deep sea sediments makes it highly probable that west-wind driven currents across a broad shelf on Campbell Plateau displaced these diatoms into the depo-center at the eastern foot of the plateau.
The implications of these findings are discussed.

Keywords: diatoms, Paleocene, paleoproductivity.

The Bartonian (Middle Eocene) GSSP: Historical considerations and challenges

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The Bartonian Stage is one of the standard stages of the Eocene. It has a complex history of usage dating from the mid-19th century. In defining its GSSP, the Bartonian Working Group plans to honor the historical concept of the Bartonian Stage as originally identified in the Hampshire Basin and will select a definition that does not truncate the "unit stratotype" of the Bartonian Stage. The Working Group recognizes that the lithostratigraphic concept of the Barton Clay Formation differs from the chronostratigraphic concept of the Bartonian Stage. It is proposed that the *Nummulites prestwichianus* bed in the Hampshire Basin be used to define the base of the historical Bartonian Stage in that region. Previously proposed guide events for the Bartonian Stage which both honor this definition and may serve to define a GSSP include either the base or the top of magnetochron C19n, the first occurrence of planktonic foraminiferan *Turborotalia cerroazulensis,* and the last occurrence of the planktonic foraminiferan *Guembelitrioides nuttalli*. Additionally, the lowest occurrence of the calcareous nannofossil *Reticulofenestra reticulata* is a widely recognized biolevel which correlates closely with the base of C19n. Ongoing biostratigraphic and magnetostratigraphic work on sections in Spain and Italy will likely produce a GSSP for the Bartonian Stage.

Keywords: Eocene, Bartonian, GSSP, Hampshire Basin, magnetostratigraphy, biostratigraphy.

Planktonic foraminiferal biostratigraphy across the Eocene/Oligocene boundary in the North Adriatic Sea

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The upper Eocene and lower Oligocene sediments from Istra more-3 and Istra more-4 wells, located on the eastern edge of the Venetian Basin, consist of hemipelagic deposits of marls and silty marls. These sediments contain abundant and very well preserved planktonic foraminiferal assemblages. The standard planktonic foraminiferal zonation of Paleogene after WADE *et al.* (2011) has been applied. The Eocene/Oligocene boundary in the Adriatic Sea is clearly defined by the extinction of all hantkeninids, the *Turborotalia cerroazulensis* group, and the last globigerinathekids species *Globigerinatheka tropicalis*, indicating strong climate deterioration and global cooling. Significant changes in small size fractions (<125μm) across the Eocene/Oligocene boundary have been observed. This boundary is also characterized by abundant occurrence of *Chiloguembelina ototara*, *Tenuitella* (*T. praegemma, T. gemma*) and by the first appearance of the tiny species *Cassigerinella chipolensis*.

Keywords: planktonic foraminifera, biostratigraphy, Eocene/Oligocene boundary, Adriatic Sea.

The Bottaccione section at Gubbio, central Italy: a classical Paleocene Tethyan setting revisited

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Available biomagnetostratigraphy suggests that the Paleocene interval in the Classical Tethyan setting of the Bottaccione section (Gubbio, central Italy), may be condensed relative to other outrcops in the area and/or that the Bottaccione succession may contain a non identified stratigraphic gap in the lower Paleocene. Yet, new integrated stratigraphic data, including bio-, magneto-, chemo-, and cyclostratigraphy, provide robust evidence that the Bottaccione section is complete and comparable to other successions outcropping in the Umbria-Marche area, which solves potential conflicts in the interpretation of the regional biostratigraphic and lithostratigraphic record. The recognition of orbitally forced sedimentary cycles together with the availability of a carbon isotope profile makes the Bottaccione outcrop a potential reference section for comparison with the already available record of carbon cycle alterations in the Early-Middle Paleocene.

Keywords: Paleocene, Integrated stratigraphy, Bottaccione.

New and revised planktonic foraminiferal bioevents of the (Middle) Eocene

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Planktonic foraminiferal evolutionary and extinction events are essential constituents in both regional and global biostratigraphy and are integral to Cenozoic chronostratigraphy. Determination of planktonic foraminiferal events has predominantly been established through magnetostratigraphic correlation of Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) cores, as well as outcrops when available. There remain many Paleogene planktonic foraminiferal events where calibration is impeded through reduced core recovery, lack of biogenic carbonate, and the absence of magnetostratigraphic and/or cyclostratigraphic age control.

Here we review critical planktonic foraminiferal bioevents of the Eocene, focusing on the Lutetian and discuss their utility and calibration to the global polarity and astronomical time scales. Planktonic foraminiferal biochronology for the middle Eocene has recently undergone extensive revisions that have resulted in large changes in the duration of biochrons. We examine planktonic foraminiferal assemblages from Ocean Drilling Project (ODP) Leg 171B, Site 1051, Blake Nose in the western North Atlantic Ocean. Planktonic foraminifera are abundant, with diverse assemblages. Quantitative biostratigraphy was conducted on planktonic foraminifera from 119 to 369 meters below sea floor. This interval corresponds to magnetochrons C18r to C21n. All planktonic foraminifera are well preserved (although recrystallized) and assemblages are diverse. We present an integrated magnetobiochronology of Middle Eocene planktonic foraminifera with significant revision and recalibration of Eocene planktonic foraminifera Zones E7 through Zone E11.

Keywords: Eocene, biostratigraphy, planktonic foraminifera.

New integrated high-resolution dinoflagellate cyst, litho- and chemo-stratigraphy from the Paris and Dieppe-Hampshire Basins "Sparnacian"

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The Paris Basin represents an historical cradle of the Paleogene stratigraphy, where the Paleocene Epoch and the "Sparnacian Stage" have been erected in XIX century. As highlighted by AUBRY *et al.* (2005), whereas the chronostratigraphic connotation of the "Sparnacian Stage" occurred to be controversial since its definition, modern studies of the Late Paleocene - Early Eocene interval have revealed that the so-called "Sparnacian" deposits encompass a remarkable and short (~170 kyr) episode in the Cenozoic history, the Paleocene-Eocene Thermal Maximum (PETM, ~55.8-55.6 Ma).
However, due to a large development of diverse and laterally variable, predominantly lagoonal and non-marine facies, the Paris Basin Upper Paleocene-Lower Eocene succession is still poorly documented and needs an updated chronostratigraphic correlation with other Paleogene records in adjacent basins and worldwide. Since almost 45 years the dinoflagellate cyst stratigraphy has significantly contributed to correlations of the Thanetian-Ypresian deposits in the Paris and adjacent basins. Nevertheless, data published on dinoflagellate cysts distribution in the Paleocene-Eocene sediments of these basins remain too scattered and need to be calibrated to the most recent biozonations.
With the aim at reconstructing the "Sparnacian" palaeoenvironments as well as ensuring correlation with the PETM (and its Carbon Isotopic Excursion, CIE) event and related processes, a number of new or already well known "Sparnacian" Dieppe-Hampshire and Paris Basins key localities have been investigated in details palynologically and chemostratigraphically. According to our new high-resolution data, the CIE begins within the Mortemer Fm in terrestrial or coastal environments and would continue until the top of the Soissonnais Fm. The CIE interval contained in the lagoonal and shallow marine units reveals an extremely pronounced *Apectodinium*-acme (70-98% of dinocyst assemblage), sometimes accompanied by *Pediastrum*-blooms (fresh water algae).
Dinoflagellate assemblages from the Dieppe-Hampshire and Paris Basins "Sparnacian" do not contain the key species *Apectodinium augustum*, whereas it is present in the northern Belgian Basin Tienen Formation and is coeval there with the CIE and *Apectodinium*-acme interval. However, our calibration of the *Apectodinium*-acme to the CIE in the Dieppe-Hampshire and Paris Basins suggests its attribution to the A. augustum zone. The absence of species *A. augustum* in the Anglo-Paris Basin may be explained by its restriction to more offshore conditions.

Keywords: PETM, "Sparnacian", Paris and Dieppe-Hampshire Basins, dinoflagellate cysts, CIE.

Palynology as a high resolution tool for cyclostratigraphy in Middle Eocene lacustrine sediments – the outstanding record of Messel (Germany)

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The annually laminated oil shale from the early Middle Eocene maar lake at Messel provides unique palaeoenvironmental and –climatological data for a time interval of ~640 kyr during the Paleogene. Therefore, the research core Messel 2001 opened an unique window into ecological changes within the Paleogene greenhouse world which are documented at the site by an undisturbed succession of 230 m of lacustrine sediments including >90 m of varved oil shale. For studying these sediments with respect to short-term climate variations different approaches such as high-resolution palynology and varve analysis have been applied. As a result, we have found changes in the vegetation following Milankovitch cycles in the range of precession, obliquity and eccentricity as well as sub-Milankovitch cycles. Furthermore ENSO signals have been detected in the varves.

Keywords: Middle Eocene, Maar Lake, Palynology, Climate variability, Eocene ENSO, Milankovitch cycles.

Paleocene-Eocene transition as reflected by mammalian evolution in central Asia

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Studies during the last two decades in the central Asia, mainly in Inner Mongolia, have greatly improved our understanding of the paleontology, biochronology and environmental changes across the Paleocene-Eocene transition in the region. Among numerous fossil mammals discoveries of important taxa of perissodactyls, lagomorphs, rodents and primates provide additional age calibrations for mammalian divergences and indicate that several placental mammal orders emerged at the beginning of the Eocene. These recently reported species furnish important morphological features that help us understand the evolution in their own lineages. Collectively, the faunal compositions show that the mammalian faunal evolution in the central Asia is probably affected by the global environmental changes across the Paleocene-Eocene transition.

Keywords: Mammals, Paleogene, Central Asia, Evolution, Environmental changes.

Biostratigraphy of the Middle Eocene Kohat Formation, Himalayan Fold and Thrust Belt, Northern Pakistan

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A section of Middle Eocene Kohat Formation has been measured from the Gumbat area, Kohat Basin, northern Pakistan for detailed biostratigraphical and micropaleontological studies. A total number of 44 samples were collected from bottom to top, keeping in view the facies variations. Out of these samples 50 thin sections were prepared. Fifteen age diagnostic species of larger foraminifera were recorded. On the basis of these age diagnostic species a late Cuisian to Mid Lutetian age has been designated to the Kohat Formation. This age falls in SBZ 12 to SBZ 14 according to the Standard Shallow Benthic Biozonation (SB Zonation). Four microfacies and eight subfacies have also been recorded ranging from Grainstone to Mudstone. On the basis of foraminiferal assemblage and the microfacies analysis, it can be concluded that the Kohat Formation in this area might have been deposited in shallow shelf, low to moderate energy environment with free circulation of water.

Keywords: Eocene, Microfacies, Biostratigraphy, Foraminifera, Biozonation.

Correlation between Shallow Benthic Zones and calcareous plankton Zones at the Bartonian-Priabonian transition: preliminary results from the Varignano section (Trento Province, northern Italy)

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The Varignano section (Trento province, northern Italy), deposited in bathyal paleoenvironment, contains eight resedimented bioclastic levels with larger foraminifera, thus providing the exceptional chance to directly correlate the Shallow Benthic Zones (SBZ) with the calcareous plankton standard Zones around the Bartonian-Priabonian transition. Moreover, this section is only 80 km far from the Alano di Piave section (Veneto region), candidate to host the GSSP of the base of Priabonian, where this direct correlation is hampered by the absence of resedimented levels across the critical interval.

The preliminary results of the integrated calcareous plankton and larger foraminifera study evidence that the extinction of morozovellids and large acarininids (E13-E14 boundary) occurs within SBZ 18 and not at the boundary SBZ 18-19 as usually considered.

Keywords: Biostratigraphy, Shallow Benthic Zones, Middle-Upper Eocene, Larger Foraminifera, Planktonic Foraminifera, Calcareous Nannoplankton.

In search of the Bartonian (Middle Eocene) GSSP (I): Potential in the Basque-Cantabrian and Aquitanian Basins (W Pyrenees)

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The Global Stratotype Section and Point (GSSP) for the base of the Bartonian (middle Eocene) stage is as yet undefined. Herein the potential of the successions found in the Basque-Cantabrian and Aquitanian basins (western Pyrenees) is analysed. On the basis of the available data, no outcrop in the Biarritz and Pamplona areas fulfilled the requirements outlined by the International Commission on Stratigraphy. However, the succession exposed on the eastern side of the Cape of Oyambre (San Vicente de la Barquera, province of Cantabria, North Spain) did and yielded positive preliminary results.

Keywords: Eocene, Bartonian, GSSP, Pyrenees, Cantabria, Oyambre.

Linked proposals to core Cenozoic marine stratigraphic reference sections onshore and offshore Tanzania (ICDP / IODP)

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Marine hemipelagic sediments of Cretaceous through Miocene age crop out across a large area along the southern coastal fringe of Tanzania, and in many places dip gently offshore beyond a narrow shelf under the current continental slope. Exploration on land, including extensive new geological mapping and a campaign of shallow drilling, has characterized much of the stratigraphy of the older part of the succession (especially Late Cretaceous and Paleogene). Offshore seismic surveying and box / piston coring in 2009 helped clarify the structure and stratigraphy from near the modern coastline to the Davie Ridge, a major structural feature ~150 km offshore. The Cenozoic succession is dominated by clay rich facies that are well known for their exceptionally well-preserved microfossils and organic biomarkers with proven potential for the application of a wide range of marine and terrestrial paleoclimate proxies allowing us to reconstruct conditions in the low-latitude ocean, atmosphere, and the adjacent African continent. Events such as the Paleocene / Eocene Thermal Maximum and Eocene / Oligocene Transition have already been recovered and studied using simple truck-mounted rigs. Now we plan to drill a series of sites with high quality coring, recovery, and logging including the Paleocene to Oligocene onshore at one site (Workshop Proposal 'Tanzania Onshore Paleogene Integrated Coring', TOPIC, to the International Continental Drilling Project, ICDP) and the Paleocene through Holocene offshore (Full proposal 778 'Tanzania Offshore Paleoclimate', TOP, to Integrated Ocean Drilling Program, IODP). The common objective of these proposals is to elucidate the Cenozoic climate history of this area and the cores will provide world class reference sections for integrated stratigraphy and geochronology in tropical latitudes.

Keywords: Paleogene, Neogene, Tanzania, Drilling, Stratigraphy.

A new low to middle latitude biozonation and revised biochronology of Paleogene calcareous nannofossils

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We present a new Paleogene calcareous nannofossil biozonation that is integrated with the biostratigraphic frameworks of Martini and Bukry (MARTINI, 1971; BUKRY, 1973, 1978; OKADA & BUKRY, 1980. Age estimates are provided for all Paleogene biohorizons. This new biostratigraphic scheme is derived from the biostratigraphic methodologies and data we have generated over nearly three decades, studying calcareous nannofossils in Paleogene marine land sections and deep-sea sediments in low and middle latitude regions. Additional new data are also presented. The aim of our work has always been to pursue a detailed nannofossil biostratigraphy through the use of semi-quantitative methods in combination with short sample distances. This strategy is aimed to

capture the details of the distribution and abundance behavior of individual calcareous nannofossil taxa. A limited set of selected biohorizons has been chosen for the purpose of establishing a relatively coarsely resolved biozonation that could guarantee ease of communication and applicability in the practical geologic work. Following the criteria used in a new Neogene biozonation recently published by BACKMAN *et al.* (2012), we propose a new code system for the 36 biozones in the interval Paleocene through Oligocene: Calcareous Nannofossil (CN) Paleocene biozones 1 through 11, CNP1 - CNP11; CN Eocene biozones 1 through 19, CNE1 - CNE19; CN Oligocene biozones 1 through 6, CNO1 - CNO6. The average duration of the biozones is 0.9 m. y. in the Paleocene, ~1 m. y. in the Eocene, 1.9 m. y. in the Oligocene. Age estimates are assigned to all biozone boundary markers and to numerous additional biohorizons. This biochronology has been derived from astronomically tuned cyclostratigraphies in the time interval from 23 to ~ 41 Ma (PÄLIKE et al., 2006) and from the GPTS of CANDE & KENT (1995) from ~ 41 to 65 Ma (to the K/Pg boundary). Emphasis is given on the discussion about the reliability of those nannofossil biohorizons that, in the past and recently, have been used or suggested for definition/recognition of some Paleogene Stage boundaries.

Keywords: Calcareous Nannofossils, Biozonation, Paleogene, biochronology.

Lower Eocene to Lower Miocene stratigraphy and paleoenvironment of ODP Site 643A, Norwegian Sea

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The focus of this study was the Lower Eocene to Lower Miocene succession in ODP Site 643A. The site is located in the Norwegian Sea, at the base of the Outer Vøring Plateau (OVP). We have analysed dinocyst assemblages and calculated the relative input of soil organic matter using an organic proxy, the BIT index. Our results suggest outer neritic/oceanic conditions during the deposition of the studied succession, and a progressive submerging of the OVP. A transition from a stratified oxygen depleted into a mixed and well oxygenated water column is observed ~41.2 Ma and might be connected with a subsidence event of the OVP. The dinocyst abundance variations indicate that there was a connected surface water circulation within the Norwegian-Greenlandic Sea in the latest Lutetian. Our record also suggests that there was a good surface water exchange between the Norwegian Sea and the North Sea Basins in the earliest Oligocene and at the Oligocene/Miocene transition.

Keywords: dinocysts, BIT, palaeoenvironment, Paleogene, Norwegian Sea, ODP Site 643A.

Oligocene planktonic foraminiferal biostratigraphy: current state-of-the-art and new calibrations

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Extinction and evolutionary events in planktonic foraminifera are extensively employed in regional and global biostratigraphy and are a fundamental component of Cenozoic chronostratigraphy. The calibration of planktonic

foraminiferal events has been based largely on correlations to the magnetostratigraphy in Deep Sea Drilling Project and Ocean Drilling Program (ODP) cores, as well as outcrop sections (BERGGREN *et al*., 1995; WADE *et al*., 2011). However, the calibration of many Paleogene planktonic foraminiferal events has been hindered by poor core recovery, the absence biogenic carbonate and a lack of magnetostratigraphic and/or cyclostratigraphic age control.

Keywords: Paleogene, biostratigraphy, planktonic foraminifera.

Paleogene marine stratigraphy in China

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Paleogene deposits are widespread in China. Most strata are non-marine origin and marine sediments occur only in Tibet, southwestern Tarim Basin of Xinjiang, and continental margin of East China Sea. Among them, Tibetan Tethys is a dominant marine area where continuous sequences are preserved. The Paleogene in Tethys-Himalaya is divided as the Danian Jidula, Ypresian to Batonian Zongpu, and Priabnian Zhepure formations.

Keywords: Paleogene, stratigraphy, Tethys-Himalaya, China.

The Levant margin in the Early and Middle Eocene: carbonate sedimentation and calcareous nannofossil trophic index

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The Early and Middle Eocene in the Levant region is represented by a monotonous chalk lithofacies, composed overwhelmingly of calcareous nannofossils or their diagenetically altered products. Hidden within this lithofacies are indications of dramatic changes in oceanic paleoenvironments which can be tracked by change in the calcareous nannofossil populations. A study of these populations was conducted on a proximal-distal transect across the Levant margin region of the Tethys. The database consists of 200 samples from 11 sites representing the Early and Middle Eocene of Israel. Localities sampled were from the Arava Valley, proximal to the Arabian platform margin, and along the Mediterranean coast, from the coastal foothills region in the south to the Menashe region to the northwest. A further set of 200 samples from an earlier study in the north-central Negev completed the transect.

A trophic index based on Chiasmolithus vs. discoaster dominance was calculated from the database. The results show that the trophic level constitutes the principal mode of paleoecological change in the oceanic water body of the Eocene sedimentary environment. Data from the full transect shows that the Arava sections stand out in this respect; on the one hand this region contributed least to variance of the trophic index, and there is a very strong covariation between the calcareous nannofossil population index and the δ13C trend. This indicates that an exceptionally stable, high-nutrient trophic system generally prevailed in the Arava region. In contrast, variance in calcareous nannofossil population indices was considerably higher on the outer Levant margin.

Relatively mild changes in the trophic level are associated with highly significant changes in population structure, as well as in carbonate and organic matter production. An equilibrium between these products reflects stable trophic conditions. Disturbance of this equilibrium, such as by increased flux of nutrients, does not correspond to increased in carbonate sedimentation rates: there is an inverse relationship between carbonate production and trophic index as determined from the nannofossil populations. When carbonate production approaches its maximum, the typical calcareous nannofossil population is dominated by larger Coccolithus-type forms and abundant discoasters, adapted to low nutrient flux. Generally, however, the trophic index of the calcareous

nannofossil population of the Arava region in the Early Eocene indicates an environment highly enriched in nutrients, and concomitantly, background carbonate production rates were low.
Events of reduced trophic index and substantial increase in carbonate production by calcareous nannofossils occurred in the Arava region in the Early Eocene, in particular, during the Early Eocene Climatic Optimum (EECO). In the Middle Eocene, increase in trophic index corresponded to falling carbonate production by the calcareous nannoplankton population.
The more distal setting of the Mediterranean coastal region was less influenced by high trophic levels in the Early Eocene, and changes were better balanced to carbonate production, increasing mildly at the EECO. However, the Middle Eocene increase in trophic level found at the NP14/15 transition was widespread, found both in proximal and distal Levant regions, and may therefore have been the product of global change.

Keywords: calcareous nannofossils, Eocene, Israel, Levant Margin, trophic index.

Rapid warming at the PETM and its influence on vegetation in Denmark

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Earliest Eocene expanded marine sedimentary successions in Denmark are of global chronostratigraphic significance deposits, due to excellent preserved terrestrial and marine fossil assemblages, combined with a number of radiometric dated ash layers. A detailed study of vegetation changes across the PETM interval have not yet been carried out, nor has the microflora e.g. spores and pollen been related the existing macrofloral remains e.g. seeds and leaves stored in Danish Museums.
This palynological research project on vegetation changes across the PETM interval is significant, because there are extremely few PETM vegetation records where a complete, high-resolution plant response to this transient event can be examined. Herein, we present preliminary mioflora results from an expanded marine PETM record in the Østerrenden drill core (DGI 83101), located in Store Bælt, Denmark. This preliminary study revealed that a distinct mioflora change correlates with the onset of the Carbon Isotopic Excursion event (CIE) in the Østerrenden drill core and the mioflora assemblage's change from low to high diversity across the Paleocene-Eocene boundary. The Paleocene assemblages comprising high relative abundance of *Inaperturopollenites* spp. (taxodiaceae), but from the very onset of the CIE event is this Paleocene assemblage type replaced by species such as *Caryapollenites circulus*, *Platycaryapollenites platycaryoides* and *Tricolpopollenites librarensis*. These typical early Eocene pollen species originate from ancestors of Juglandecaceae (walnut) and Fagus (beech) families. Paleotropical floral elements such as palm pollen (*Arecipites* spp.) and angiosperm pollen from *Anacolosa* spp. (Olacaceae) also occur for the first time in the basal Eocene part of the Østerrenden drill core. An increased influx of pollen typical of wet lowland area such as *Sparganiaceaepollenites* spp. (Typhaceae) is also observed, indicating a change in the hydrological regime towards increased seasonality during the earliest Eocene.

Keywords: Palynology, spores and pollen, PETM vegetation, Paleocene-Eocene boundary, Denmark.

Mass extinction and turnover at the Cretaceous-Paleogene boundary in the Izeh section (Zagros Basin, SW Iran)

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A detailed study of uppermost Maastrichtian-lower Danian marls, from Gurpi Formation, deposited above the compensation depth at the Izeh section (central part of the Zagros Bassin, SW Iran) has yielded diverse and abundant planktonic foraminifera. Their distribution allows the Cretaceous-Paleogene boundary to be placed at about 1.5 m from the base of the studied series, where an iridium anomaly occurs. Within this series all the characteristic planktonic foraminiferal biozones are recorded. Besides it allows the model of extinction and turnover to be commented.

Keywords: K/Pg boundary, Planktonic foraminifera, Extintion, Turnover, Zagros.

The criteria for the Bartonian boundaries in North-Eastern Peritethyan and Tethyan areas

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The Bartonian base in recent standard scale is not marked by any bioevents in planktonic microfossils (planktonic foraminifera, nannoplankton) succession. The definition of Bartonian base and top in NE Peritethys is hampered also due to cardinally difference of planktonic foraminifera (PF) from Tethyan ones and absence of larger benthic foraminifera (LBF). The correlation of Peritethyan and Tethyan planktonic zones for Bartonian is possible in Armenia. Such correlation showed the diachronous position of Bartonian PF zones in these two paleogeographic regions. The revision of nummulitic zonation of Armenia in this interval is the future task. But the study of LBF from *N. perforatus* and *N. millecaput* horizons and *N. fabianii* zone in Vedi section allowed to distinguish here the intervals of SBZ17, SBZ18 and SBZ19 zones of Tethyan shallow benthic zonation, which can be correlated with P12?, P13-P16 planktonic foraminiferal standard zones. The bioevents in LBF on Bartonian/Priabonian boundary is considered in Vedi section, where the gradual extinction of giant *Nummulites* corresponds to gradual occurrence of reticulate *Nummulites* and genus *Spiroclypeus*. The variants of Bartonian/Priabonian boundary are discussed.

Keywords: Bartonian, Nort-Eastern Peritethys, Tethys, correlation, foraminifera.