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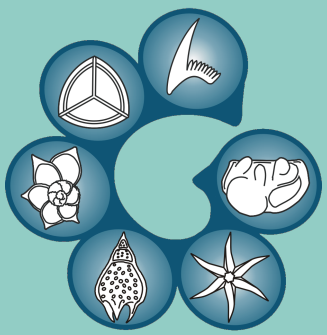
The Micropalaeontological Society Annual Conference 2021

At the interfaces of geological periods—the contribution of micropalaeontology to the reconstruction of events in the boundary intervals



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Organizing committee:

- doc. RNDr. Katarína Holcová, CSc.
- Dr Filip Scheiner
- Dr Manuel F. G. Weinkauf

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Foreword

***Katarína Holcová*, Univerzita Karlova (Czech Republic)**

Dear participants of the TMS Annual Conference 2021.

I would like to welcome you, at least virtually, at the Institute of Geology and Palaeontology of the Univerzita Karlova. The history of micropalaeontology at our institute is almost 100 years old and is associated with personalities such as foraminiferologist Alfred Liebus, palynologist Blanka Pacltová, and especially ostracodologist Vladimir Pokorny, whose 100th birthday we will commemorate next year.

I wish you a successful presentation of your scientific results, lots of new and interesting information about the fossil microworld, and enriching discussions. Here's hoping that we will be able to meet in person next year.

Katarína Holcová
Head of the Institute of Geology and Palaeontology
Univerzita Karlova in Prague

Programme

*All times are given as Cenral European Time (CET). Please adapt accordingly if you reside in a different time zone, e.g. using https://www.timezoneconverter.com.

Thursday, 18 November 2021

Time*	Programme
10:00–10:30	**Opening ceremony**
	Regular talks (chaired by Michal Kučera)
10:30–10:45	Conflicting priorities and concepts in nannoplankton taxonomy *Jeremy Young*
10:45–11:00	Foraminiferal organic linings: Emerging phylogenetic trends and research challenges *Jarosław Tyszka*
11:00–11:15	A planktonic Foraminifera taxonomical puzzle: The case of Miocene *Sphaerodinellopsis kochi* *Alessio Fabbrini*
11:15–11:30	Evolving ecology and morphology of Neogene planktonic Foraminifera *Grace Lamyman*
11:30–11:45	Preliminary results from large-scale culturing experiments on *N. pachyderma*: Development of a proxy toolbox for polar ocean surface hydrography *Adele Westgård*
11:45–12:30	Lunch break
	Keynote talks (chaired by Jarosław Tyszka)
12:30–13:15	The GSSP definition-pitfalls in multiproxies: An example from the Devonian *Ladislav Slavík*
13:15–14:00	Calpionellids and calcareous nannofossils as a tools of the biostratigraphic correlation of Upper Jurassic–Lower Cretaceous sedimentary sequences of the Tethyan area *Daniela Reháková* and *Andrea Svobodová*

Time*	Programme
14:00–14:45	Palynology, Rocks, and Earth's History: A holistic approach *Francisca Oboh-Ikuenobe*
14:45-15:00	Coffee break
	Regular talks (chaired by Filip Scheiner)
15:00–15:15	Planktonic Foraminifera records at Site IODP 1308 during the mid-Pleistocene transition (marine isotope stages 26 to 21) *Maryline Mleneck-Vautravers*
15:15–15:30	Comparison of the calcareous nannofossils assemblages from different chalks for artworks provenance *Victory Jaques*
15:30–15:45	Using silicon isotopes and diatom assemblages to assess nutrient cycling in the Bering Sea during the mid-Pleistocene transition *Savannah Worne*
15:45–16:00	Palynofacies and thermal maturity studies of the Kudu-3 Well, central Bida Basin, Nigeria *Jacinta Chukwuma-Orji*
16:00–16:15	How useful are calcareous nannofossils for dating rocks? An example in the Northern Calcareous Alps, Austria *Ángela Fraguas*
16:15–16:30	Planktonic Foraminifera size variation analysis: How choosing the wrong descriptor can lead to wrong assumptions *Jaime Yesid Suárez-Ibarra*
16:30–16:45	Coffee break
16:45–18:30	**TMS Annual General Meeting**

Friday, 19 November 2021

Time*	Programme
	Regular talks (chaired by Francesca Lozar)
8:30–8:45	Late Miocene to Pleistocene calcareous nannofossil events from the northeast Indian Ocean *Lopamudra Roy*

Time*	Programme
8:45–9:00	Late Miocene calcareous nannofossils from Neil Island, northeast Indian Ocean *Stuti Saxena*
9:00–9:15	Impact of radiolarians on Neil Island of the Andaman and Nicobar basins, northeast Indian Ocean *Rikee Dey*
9:15–9:30	Palynology of evaporites: Case studies and a bright future ahead *Gil Machado*
9:30–9:45	Microbioerosion on the Late Triassic to Middle Jurassic Foraminfera from the Dachstein limestones in Northern Calcareous Alps, Austria *Matic Rifl*
9:45–10:00	Coffee break
	Keynote talks (chaired by Jeremy Young)
10:00–10:45	Ecosystem responses in an ancient sister lake system from MIS 5 to present: The diatom record of lakes Ohrid and Prespa *Aleksandra Cvetkoska*
10:45–11:30	End-Cretaceous extinction, recovery, and radiation of the Paleocene–Eocene Foraminifera: Multiproxy data from the Western Carpathians *Ján Soták*
11:30–12:15	Long lived lakes of the central Paratethys—hot spots of Miocene biodiversity *Radovan Kyška Pipík*
12:15–13:00	Lunch break
13:00–13:30	**Poster session (chaired by Valeria Luciani)**
	Foraminiferal associations of Vienna Basin based on the borehole MZ 102 *Jaroslava Babejová-Kmecová*
	Biostratigraphic and palaeoecological evaluation of planktonic and benthic Foraminifera across the Albian–Cenomanian transition *Tímea Aranyi*
	Global database of foraminiferal organic linings *Karolina Godos*
	Morphological variation in the extant coccolithophore genus *Palusphaera* (Prymnesiophyceae) *Odysseus Archontikis*

Time*	Programme
	Nutrient availability mediated response of eutrophic lake to climatic change at Late-Glacial/Holocene transition—diatom record from Central Europe *Anna Tichá*
	Calcareous nannofossil biostratigraphy of the 'Dan-01' Well, offshore Niger Delta, south-South Nigeria *Mayowa Ajayi*
	Mg/Ca palaeotemperatures at the Early Eocene climatic optimum from Southern Atlantic Site 1263: Link to changes in planktonic foraminiferal assemblages? *Antonella Gandolfi*
	Reconstruction of the Upper Pleistocene–Holocene palaeoenvironment in the western Mediterranean (Alboran Sea) based on dinoflagellate cysts records *Jihad Rachid*
	Conjoined tests in epiphytic populations of *Sorites*: Insights into the occurrence of tests with multiple proloculi in fusulinids *Susan Richardson*
13:30–14:00	Breakout room discussions
	Regular talks (chaired by Manuel Weinkauf)
14:00–14:15	Cenomanian biostratigraphy: A review *Mike Bidgood*
14:15–14:30	Palaeoceanographic changes registered by planktonic Foraminifera across the Cenomanian–Turonian OAE 2 at high latitudes (IODP U1516, SE Indian Ocean) *Maria Rose Petrizzo*
14:30–14:45	Caenozoic climate regime drove spatial patterns in speciation and dispersal dynamics of planktonic Foraminifera *Adam Woodhouse*
14:45–15:00	Impact of Early Eocene climatic optimum on planktonic Foraminifera from the Pacific Ocean: Morozovellids marked decline and change in coiling direction *Giulia Filippi*
15:00–15:15	Foraminiferal and calcareous nannofossil resilience to the Middle Eocene climatic optimum as recorded from the Tethyan Baskil section (eastern Turkey) *Roberta D'Onofrio*
15:15–15:30	Coffee break

Time*	Programme
	Regular talks (chaired by Joachim Schönfeld)
15:30–15:45	Defining reference conditions and assessing anthropogenic effect on ecosystem quality in transitional waters, using benthic foraminiferal indices *Pheobe O'Brien*
15:45–16:00	Late Miocene benthic Foraminifera from the Sinu-San Jacinto Basin (Northern Colombia) and their palaeoenvironmental implications *Sofía Barragán-Montilla*
16:00–16:15	Size matters at the MSC-onset: Narrative of an adaptation *Francesco Pilade*
16:15–16:30	Finite element analysis: A method to assess the impact of climate change on the structural integrity of benthic Foraminifera *James Mulqueeney*
16:30–16:45	Benthic Foraminifera oxygen and carbon isotopes offsets over the last 40 000 years as recorded in eastern tropical Pacific Site ODP 1242 *Babette Hoogakker*
16:45-17:15	**Closing ceremony**

Contents

Part I

Annual Conference 2021—Keynotes

Ecosystem responses in an ancient sister lake system from MIS 5 to present: The diatom record of lakes Ohrid and Prespa

Aleksandra Cvetkoska[1]

[1]Department of Aquatic Ecology, Nederlands Instituut voor Ecologie (NIOO-KNAW), Wageningen, The Netherlands

✉ A.Cvetkoska@nioo.knaw.nl

The Quaternary is a period of fluctuating, glacial–interglacial climates and there is a vast evidence for the effects of those variations on the ecosystems and their biota from various marine and continental sediment records. However, the number of continental fossil diatom records with such a geochronology is fundamentally limited to few ancient lakes, with uneven spatial distribution over the globe and preservation of frustules.

Balkan 'sister' lakes Ohrid and Prespa (Fig. 1) co-existed for more than 1 Ma thus, representing the oldest and most diverse permanent freshwater system in Europe (Stanković 1960). The lakes share an underground hydrological connection via a karstic system in Mt. Galicica, but differ substantially in their physical and chemical properties. Recent studies presumed that the much shallower and nutrient-rich Lake Prespa can potentially affect the nutrient availability and endemic biodiversity of the deep and oligotrophic Lake Ohrid.

In 2013, a coring campaign was carried out under the umbrella of the International Continental Scientific Drilling Program and a 584-m sediment succession (DEEP-5045-1) was retrieved from the central part of the lake at a water depth of 243 m (Francke et al. 2016). The upper 446.65 mcd represent the entire lacustrine history back to *c.*1.363 Ma. The longest core, Co1215, from Lake Prespa was retrieved in 2009 from the northern central part of the lake at a water depth of 14 m. The core is 17.7 m long and spans the last *c.*92.0 ka. In this keynote talk, I will focus on the diatom records and present the eco-stratigraphic changes of both lakes that took place during

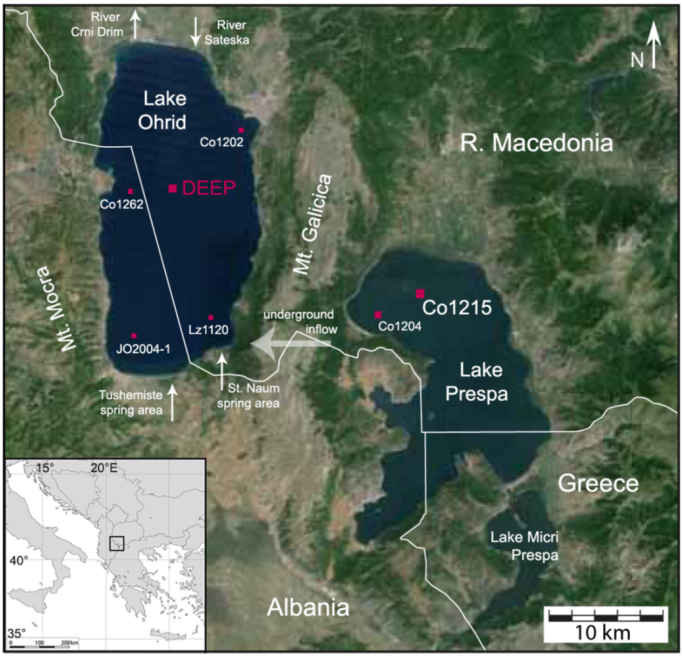

Figure 1: Map of the northern Mediterranean region showing the location of lakes Ohrid and Prespa. Marked are the locations of several short cores recovered during field campaigns between 2004 and 2009, and the two cores that will be discussed in this keynote talk: Co1215 recovered from Lake Prespa and the DEEP site core 5045-1, retrieved during the SCOPSCO deep drilling campaign at Lake Ohrid. Modified from Cvetkoska et al. (2016).

the last 92 ka. Through comparison with palaeoenvironmental data from both cores, I will discuss the main drivers of community structure. Finally, I will compare the ecosystem's palaeoecology and discuss the potential interconnectivity between the lakes since the last glacial–interglacial.

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Palynology, rocks and Earth's history: A holistic approach

***Francisca Oboh-Ikuenobe*[1]**

[1]Department of Geosciences and Geological and Petroleum Engineering, Missouri University of Science and Technology, Rolla (MO), USA

✉ ikuenobe@mst.edu

Organic-walled microfossils preserved in the rock record provide valuable information about the earth's evolution. Derived from every kingdom except Archaebacteria and present in different environments since the Proterozoic, their main attribute is their extreme resistance to physical destruction over time. Terrestrially derived palynomorphs like spores and pollen may be transported for some considerable distance out to the sea and do not have environmental restrictions like other microfossils such as Foraminifera and calcareous nannoplankton, making them useful for correlating non-marine and marine sequences. Palynology has important applications in petroleum and coal exploration, palaeovegetation and palaeoclimate reconstructions, sequence stratigraphy, archaeology, plant evolution, and criminal investigations. In this presentation, case studies from several localities will be used to highlight some of these applications in Mesozoic and

Caenozoic sequences. These studies include the use of key palynomorphs for biostratigraphy (ODP Leg 159, eastern Equatorial Atlantic), integrated palynological, sedimentological, and geochemical data for source rock identification (Western Desert, Egypt), and forensic finger printing based on spore and pollen sampled from clothes, hair, and skin (New Zealand, Iraq). A melissopalynological study of seasonal honey production in East Texas documents how knowledge of the flowers found attractive by bees helped in planning a bee-free and safer garden. Palynomorph data in lake sediments (Western Australia) provides useful information on prevailing climate, lake levels and ecological conditions.

Long lived lakes of the Central Paratethys—hot spots of Miocene biodiversity

Radovan Pipík[1]

[1]Earth Science Institute, Slovenská akadémia vied, Banská Bystrica, Slovakia

✉ pipik@savbb.sk

The tectonic evolution of the Alps–Carpathians–Dinarides territory in the Neogene led to a reduction of the marine water body, drop of salinity, and emergence of the brackish and freshwater lakes of which the Lake Pannon was the largest. This was a challenge for the polymorphic brackish ostracods of the Sarmatian Sea to adapt to empty ecological niches of the Lake Pannon and to freshwater intra-mountain basins. The ostracods of the freshwater origin also profited of the new limnic space and achieved high species and morphological diversity displaying many convergent morphological characters. These benthic, bathymetrically clearly differentiated endemic taxa lived and flourished in muddy, fully oxic environments, locally effected by anoxic events. Their evolutionary success is related to sexual reproduction while the ostracods—similar to extant holarctic and cosmopolitan fauna,

several of them parthenogenetic—occupied the marshes, oxbows, estuaries, and ephemeral lakes at the lake margins.

The endemic fauna went extinct due to the demise of the freshwater intra-mountain lakes, or perhaps their descendants survived in Lake Ohrid. A sudden retreat of the Lake Pannon after 9.8 Ma led to the development of extensive alluvial lowlands as well as ephemeral lakes and swamps and the endemic brackish species became extinct or shifted to the Eastern Paratethys and Mediterranean during the Messinian 'Lago-Mare' event (Fig. 2). The specific taxa are still living in the brackish Caspian Lake, brackish lakes of Central Asia, and in the Eastern Mediterranean.

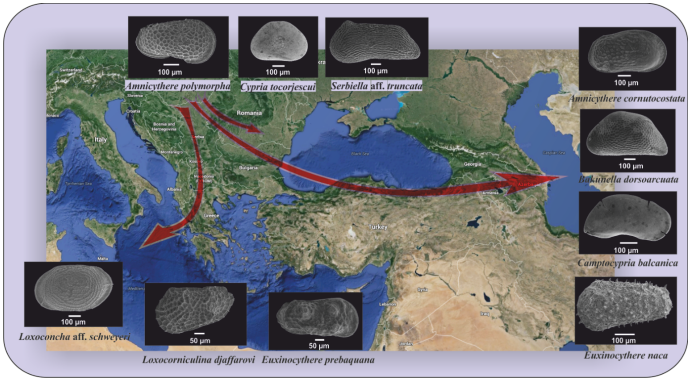

Figure 2: Migration of the brackish ostracods to the Eastern Paratethys and Mediterranean during the latest Miocene time (Kovács 2019).

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Calpionellids and calcareous nannofossils as a tool of the biostratigraphic correlation of Upper Jurassic–Lower Cretaceous sedimentary sequences of the Tethyan area

Daniela Reháková[1] and Andrea Svobodová[2]

[1]Department of Geology and Palaeontology, Univerzita Komenského v Bratislave, Bratislava, Slovakia; [2]Institute of Geology, Akademie věd České republiky, Prague, Czech Republic

✉ daniela.rehakova@uniba.sk

Calpionellids—probably ancient loricate planktonic ciliate protozoans—exhibit generally comparable morphological aspects and assemblages, so that their successive, rapidly changing events are favourable for interregional correlations and so they play a key role in the biostratigraphy of Upper Jurassic/Lower Cretaceous (J/K) sequences. These events allowed to create a widely accepted calpionellid zonal scheme (Remane et al. 1986) that was later tested and accepted across the entire Tethyan realm (Lakova and Petrova 2013, López-Martínez et al. 2015); it comprises seven calpionellid interval zones and 12–15 subzones, which were originally defined on regional levels, but the majority of them was confirmed to be of interregional relevancy.

As oligotrophic organisms, calpionellids were very sensitive to environmental perturbations, such as changes of water temperature, chemistry, salinity, and nutrient supply. The abundance and size of calpionellid loricae were influenced by water temperature and sea-level fluctuations and the size of loricae decreased towards the open sea (Reháková 2019).

The most recent studies (Wimbledon et al. 2020a, Wimbledon et al. 2020b, Casellato and Erba 2021) on the distribution of calcareous nannofossils show a close relationship between the calpionellid and nannofossil events, which seem to have resulted from the position of these microplanktonic groups in their trophic level—producers versus consumers. A revised nannofossil zonation of the Tithonian–early Berriasian interval established six zones including eight subzones. Casellato and Erba (2021) distinguished

also several highly reliable nannofossil events and evaluated them against magnetostratigraphy and calpionellid zones. Later, highly reliable events represented by the first occurrences of *Nannoconus wintereri*, *N. steinmannii minor*, and *N. kamptneri minor* were identified close to the onset of the *Alpina* event (Kowal-Kasprzyk and Reháková 2019) in the *Alpina* subzone of the *Calpionella* zone, which is a very good argument for the acceptance of all these events as supporting markers for the J/K boundary limit.

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The GSSP definition—pitfalls in multiproxies: An example from the Devonian

***Ladislav Slavík*[1]**

[1]Institute of Geology, Akademie věd České republiky, Prague, Czech Republic

✉ slavik@gli.cas.cz

A multi-proxy approach was applied during past years for correlation of carbonate and shale dominated strata in many mid-Palaeozoic regions. These include areas in peri-Gondwana and even more distant areas. A well-working biostratigraphic framework enabled application of various complementary multiproxies in order to improve correlation of sedimentary sequences and thus attain the highest precision possible. The petro–chemo-physical proxies mostly include magnetic susceptibility, gamma ray spectromentry, isotope studies, and elemental geochemistry. In reality we are, however, often facing a situation where the most needed data are missing at critical stratigraphic levels (e.g. stratigraphic boundaries and significant events). It represents a substantial constraint as the stratigraphic framework is fundamental for most subsequent geological studies and orientation in geological time.

The aim of the presentation is to show examples of the maximal precision in correlation attained using integration of several methods in contrast to some principal drawbacks that cause serious inaccuracies. For example, the use of ill-defined biostratigraphic units seriously distorted the global correlation in various intervals of the Palaeozoic and thus large errors were implied. As a consequence of misinterpretation of biostratigraphy on one hand, and inconsistency in radiometric data on the other hand, examples of major problematic issues in mid-Palaeozoic stratigraphy that have a serious impact on the GSSP concept will be demonstrated.

End-Cretaceous extinction, recovery, and radiation of the Palaeocene–Eocene Foraminifera: Multiproxy data from the Western Carpathians

Ján Soták[1]

[1]Earth Science Institute, Slovenská akadémia vied, Banská Bystrica, Slovakia

✉ sotak@savbb.sk

The Cretaceous/Palaeogene (K/Pg) boundary has been previously constrained in the Western Carpathians, but its existence is still uncertain due to Laramian erosion and the absence of the lowermost P-series biozones. New evidence of the K/Pg boundary has been gathered from the study of drill core sections from the Horná Nitra depression and Middle Váh valley areas.

The K/Pg transition is most properly marked in the Kršteňany KRS-3 section by the last occurrence of *Abathomphalus mayaroensis*. Post-K/Pg recovery is recorded by the appearance of the microperforate species *Globoconusa daubjergensis*, *Eoglobigerina simplicissima*, and *Parvularugoglobigerina eugubina* (P0–P*α* zones). The section grades upward to the Selandian formation with praemuricid species and later the radiation of morozovellids, igorinids, and fasciculiths. The Thanetian formation is dated by *Globanomalina pseudomenardii*. The Palaeocene–Eocene thermal maximum interval is marked by excursion taxa (*Acarenina sibaiyensis*, *Discoaster araneus*) in magnetic reversal Chron C24r, followed by the Ypresian formations with rich and diversified hispid morozovellid species (*M. formosa*, *M. subbotinae*, *M. aragonensis*, *M. lensiformis*, etc.), and higher up in the Lutetian formations by associations of *Morozovella gorrondatxensis*, *Turborotalia frontosa*, *Globigerinatheka kugleri*, *Acarinina topilensis*, *Morozovelloides* cf. *coronatus*, etc.

The Žilina–Hradisko section (Fig. 3) exhibits a continuous K/Pg boundary sequence, passing through the light grey Maastrichtian marlstones with rich globotruncanid and heterohelicid microfauna, across the dark grey

bioturbated marls of the lowermost Palaeocene formations with disaster species like *Guembelitria* and *Globoconusa*. Beside the abrupt biotic changes, the K/Pg boundary is marked by elevated Hg concentrations. The planktonic foraminiferal microfauna is enriched during the late Danian by species of parasubbotinids, eoglobigerinids, and praemuricids. The Lower Selandian microfauna is rich of morozovellid foraminifers like *M. angulata*, *M. acuta*, and *M. conicotruncana* (P3b zone). Globanomalinid foraminifers belong to species *G. ehrenbergeri* (P3 zone) and its descendant species *G. pseudomenardi* (P4 zone). After the disappearance of *G. pseuodomenardii*, younger species of globanomalinids like *G. chapmani* and *G. australiformis* appeared during the Late Thanetian. Morozovellid foraminifers occurred as large-sized discoidal and biconvex species belonging to *Morozovella velascoensis* zone (P5). The Palaeocene/Eocene boundary in the Žilina–Hradisko section is approximated by the species *Morozovella marginodentata* and *M. gracilis*, which first appeared in the P5 zone and terminated the E1–E3 zones (Ypresian).

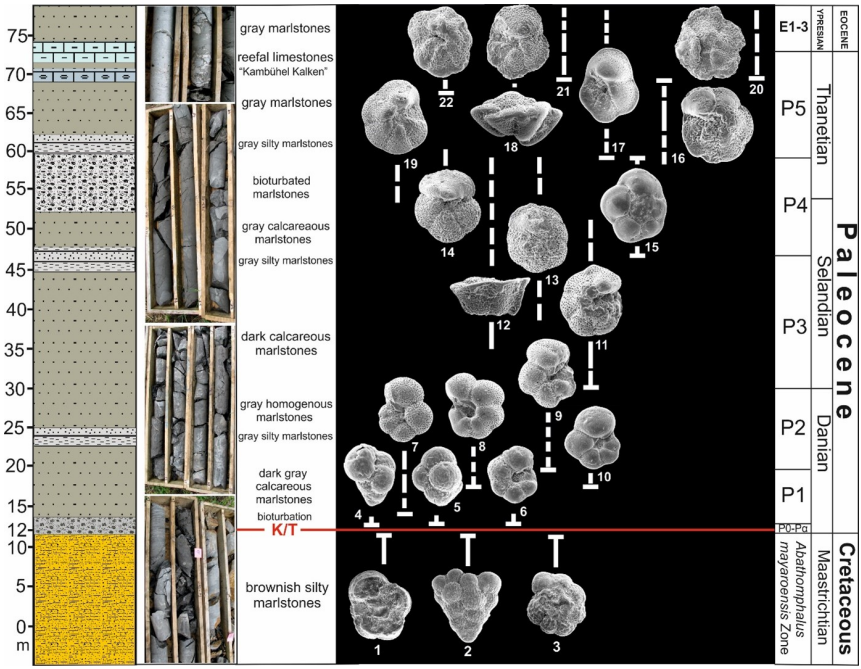

Figure 3: Lithology and biostratigraphy of the Žilina core section. Vertical distribution of marker species of planktonic foraminiferal zones and stratigraphic stage boundaries. Numbers of indicated species: 1—*Abathomphalus mayaroensis*; 2—*Racemiguembelina fructicosa*; 3—*Rugoglobigerina pennyi*; 4—*Guembelitria cretacea*; 5—*Globoconusa daubjergensis*; 6—*Parvularugoglobigerina eugubina*; 7—*Parasubbotina pseudobulloides*; 8—*Praemurica inconstans*; 9—*Praemurica uncinata*; 10—*Globanomalina compressa*; 11—*Morozovella angulata*; 12—*Morozovella conicotruncana*; 13—*Igorina albeari*; 14—*Morozovella apanthesma*; 15—*Globanomalina pseudomenardii*; 16—*Morozovella velascoensis*; 17—*Morozovella subbotinae*; 18—*Morozovella occlusa*; 19—*Morozovella acuta*; 20—*Morozovella marginodentata*; 21—*Morozovella gracilis*; 22—*Planorotalites pseudoscitula*.

Part II

Annual Conference 2021—Talks

Late Miocene benthic Foraminifera from the Sinu–San Jacinto basin (Northern Colombia) and their palaeoenvironmental implications

Sofía Barragán-Montilla[1], Claudia Patricia Cárdenas Gómez[1], and Guillermo Rodríguez-Forero[1]

[1]TIP CISLAB Colombia, Cooperativa de Tecnólogos e Ingenieros de la Industria del Petróleo y afines, Piedecuesta, Colombia

✉ sobarraganmo@gmail.com

Although special attention has been paid to the Caenozoic tectonic evolution of the Colombian Caribbean, significant variations of marine environments have also controlled marine deposition in this area. These marine deposits contain an abundant microfossil recovery dominated by benthic Foraminifera, which in addition to their excellent preservation, makes this microfossil group a key tool to characterize marine environments and their evolution in this area.

The Sinu–San Jacinto Basin presents an opportunity to investigate the Caenozoic benthic Foraminifera of Colombia offering as well a detailed picture of the palaeoenvironmental evolution. This study focused on the late Miocene from two outcrop sections (western and eastern) in the Broqueles Creek area. We studied 59 samples recovering microfossil content of 94 species and 90 genera of benthic Foraminifera, and their taxonomical and quantitative analysis allowed us to propose a detailed palaeoenvironmental reconstruction. Additionally, the occurrence of planktonic Foraminifera *Globoturborotalita decoraperta*, *Neogloboquadrina acostaensis*, *Globigerinoides bulloideus*, and *Globorotalia merotumida*, indicate a late Miocene–early Pliocene age.

For the Serravallian, the agglutinated association *Trochammina* spp., texturlaiids, *Ammoglobigerina* spp., *Haplophragmoides carinata*, and *Praesphaerammina* spp. indicate upper bathyal, oxygenated, and mesotrophic environments for the late Miocene. While at the end of the Miocene and

beginning of the Pliocene (Tortonian–Zanclean), a drop in oxygenation and an increase in trophic levels led to stress environments, represented by a decrease in diversity and the appearance of the homogeneous-calcareous association *Bolivina interjuncta* and *Uvigerina peregrina*. This stress interval was seen in both sections, suggesting that further Foraminifera studies involving other proxies should be made to determine its geographical and time extent, as well as its correlation potential in the Colombian Caribbean.

Cenomanian biostratigraphy: A review

Mike Bidgood[1] and Mike Simmons[2]

[1]GSS Geoscience Ltd., Aberdeenshire, UK; [2]Halliburton, Abingdon, UK

✉ mike@gssgeoscience.co.uk

Biostratigraphy remains the primary means of assessing if similar geological events observed in different basins or on different continents are the same event—a synchronous sea-level change for example, to establish its eustatic origin. This often requires comparison of the events as calibrated using different biostratigraphic schema, moreover, schema from different fossil groups. Thus calibration between biozonation schemes and to the standard geological timescale is of prime importance. However this can be far from straight-forward. To illustrate the issues we examine biostratigraphic calibration in the mid-Cretaceous Cenomanian stage.

Key issues are uncertainty in the calibration of the planktonic foraminiferal zonation to the ammonite ‘standard’. Competing versions of how standard well-known biozones and their defining events (e.g. first appearance datum of *Rotalipora cushmani*) need to be resolved. For some fossil groups (e.g. larger benthic Foraminifera) no standard zonation exists, thus one had to be created from a critical review of stratigraphic ranges in the

literature, with issues to be resolved including taxonomic identify, justification for stratigraphic range, and circular reasoning regarding age range. The use of stable isotopic curves as a possible calibration mechanism can be useful. Finally, even the duration of the Cenomanian stage is contentious—with radiometric and orbital forcing cycles offering substantially different results!

Palynofacies and thermal maturity studies of the Kudu-3 Well, central Bida Basin, Nigeria

Jacinta Chukwuma-Orji[1] and Joseph Titus[1]

[1]Department of Geology, Federal University of Technology Minna, Minna, Nigeria

✉ jacinta@futminna.edu.ng

Petroleum prospectivity of Bida Basin is still in its initial stage of exploration. Palynofacies and thermal maturation studies are key parameters for early basin evaluation by improving exploration success and understanding the potential hydrocarbon source rock. The purpose of this study is to carry out palynofacies characterization of the sediments retrieved from the Kudu-3 well, central Bida Basin, in order to determine the sediment maturity. These were accomplished by processing 19 ditch cutting samples within the depth interval of 31–58 m using acid maceration technique. Microscopic analyses of both palynofacies slides yielded diverse pollen, spores, dinoflagellate, and palynomacerals. The palynomaceral types recovered include 51 % of dark orange structureless resinous cortex material of Palynomaceral 1, 32 % of brown to orange platy like structured plant materials of Palynomaceral 2, 14 % of pale-coloured small to medium-sized stomata bearing plant materials of Palynomaceral 3, and 3 % of black equant needle shaped plant materials of Palynomaceral 4. Thermal maturation was determined from microscopic observation of exine wall

colour of the palynomorphs and the palynomacerals, which range from orange-brown, light-brown, and light-medium brown to dark brown. The estimated values for the thermal alteration index, vitrinite reflectance, and burial temperature extrapolated from the correlation of pollen/spore colour with other calibrated scale yielded 3/4–5, 0.55–0.95 %, and 60–120 °C, respectively. These values indicate early mature to mature stage of petroleum generation.

Impact of radiolarians on Neil Island of the Andaman and Nicobar basins, northeast Indian Ocean

Rikee Dey[1,2], Amit K. Ghosh[1], and Ajoy Kumar Bhaumik[2]

[1]Marine Micropalaeontology, Birbal Sahni Institute of Palaeosciences, Lucknow, India; [2] Applied Geology, Indian Institute of Technology (Indian School of Mines), Dhanbad, India

✉ rikeedey@gmail.com

One-hundred-and-two species belonging to 56 radiolarian genera have been identified from an outcrop situated on the east coast of Neil Island of Ritchie's Archipelago belonging to the Andaman–Nicobar Group. Detailed studies on radiolarians have been carried out in 20 samples collected from the outcrop that has been designated as Sawai Bay formation. Determined from some significant radiolarian events, the biostratigraphy has been established. The Tortonian–Messinian boundary in the outcrop has been demarcated owing to the presence of important radiolarian events, viz. the evolutionary transitions of *Didymocyrtis antepenultima* to *Didymocyrtis penultima* and *Stichocorys delmontensis* to *Stichocorys peregrina*. Based on the index-radiolarian taxa in the studied samples, the entire sequence is assignable to the RN8 and RN9 zones. Diversity analyses have been carried out to estimate the diversity and dominance of the radiolarian taxa. Attempts have been made to interpret the palaeoecology using WADE in-

dex analysis that provides a clear picture of the past environmental condition during that time slice.

Foraminiferal and calcareous nannofossil resilience to the Middle Eocene climatic optimum as recorded from the Tethyan Baskil section (eastern Turkey)

Roberta D'Onofrio[1], Amr S. Zaky[2,3], Fabrizio Frontalini[4], Valeria Luciani[1], Rita Catanzariti[5], Fabio Francescangeli[6], Martino Giorgioni[7], Rodolfo Coccioni[4], Ercan Özcan[8], and Luigi Jovane[7]

[1]Department of Physics and Earth Sciences, Università degli Studi di Ferrara, Ferrara, Italy; [2]Institute of Geological Sciences & Oeschger Centre for Climate Change Research, Universität Bern, Bern, Switzerland; [3]Geology Department, Faculty of Science, Menoufia University, Shebin El-kom, Egypt; [4]Department of Pure and Applied Sciences, Università degli Studi di Urbino 'Carlo Bo', Urbino, Italy; [5]Institute of Geosciences and Earth Resources, Consiglio Nazionale delle Ricerche, Pisa, Italy; [6]Centre for Earth System Research and Sustainability, Universität Hamburg, Hamburg, Germany; [7]Institute of Geosciences, Universidade de Brasília, Brasilia, Brazil; [8]Department of Geological Engineering, Istanbul Technical University, Instanbul, Turkey

✉ dnfrrt@unife.it

The Middle Eocene climatic optimum (MECO; ~40 Ma), which interrupted for ~5–600 kyrs the long-term cooling trend culminating at the Eocene/Oligocene boundary, still requires comprehensive biotic resilience understanding. Here, we present a high-resolution integrated foraminiferal and calcareous nannofossil study across the MECO from the expanded and continuous Tethyan Baskil section which offers a complete magneto-biostratigraphic and geochemical framework. During the pre-MECO, well stratified water column and oligotrophic conditions prevailed as indicated by abundant oligotrophic nannofossil indices and by both surface dweller planktic Foraminifera, dominated by oligotrophic large *Acarinina*, and ther-

mocline dwellers. Low abundance of bi-triserial benthic Foraminifera and high abundance of *Nuttallides* suggest low to moderate food supply to the seafloor. During the initial MECO and MECO $\delta^{13}C$ negative excursion, the temperature rise was linked to enhanced carbonate dissolution and to a shift towards eu–mesotrophic conditions, possibly related to accelerated hydrological cycle. The most striking biotic changes occurred at the MECO warming peak marking the highest carbonate dissolution interval. These changes include peak in warm (*C. pelagicus*, *E. formosa*, *Discoaster*, *Sphenolithus*) and eutrophic (*Helicosphaera*, *C. pelagicus*) nannofossils, virtual disappearance of the oligotrophic planktic foraminiferal large *Acarinina* and *Morozovelloides*, and peak in eutrophic deep dwellers *Subbotina*. Benthic Foraminifera suggest a decrease in the exported organic matter to the seafloor but an improvement of its quality. The post-MECO interval marks the recovery to the pre-event conditions. However, large *Acarinina* and *Morozovelloides* did not restore their abundance, possibly due to the post-MECO cooling. Our reconstruction reveals how palaeoenvironment and marine biota from the studied Neo-Tethyan setting reacted to the global MECO perturbation recording transient and permanent changes.

A planktonic Foraminifera taxonomical puzzle: The case of Miocene *Sphaerodinellopsis kochi*

Alessio Fabbrini[1], Ilaria Zaminga[1], Bridget Wade[1], and Thomas Ezard[2]

[1]Department of Earth Sciences, University College London, London, UK; [2]National Oceanography Centre Southampton, University of Southampton, Southampton, UK

✉ a.fabbrini@ucl.ac.uk

The taxonomy and phylogeny of the Miocene to Recent genera *Sphaeroidinellopsis–Sphaeroidinella* has been documented in previous studies, but the evolution of this lineage remain unclear. Some authors have debated

on this genus in the past, choosing a variety of parameters to discriminate the morphospecies. Here, we present new scanning electron microscope analyses on specimens from the Ocean Drilling Program (ODP) Site 925 (Ceara Rise, western equatorial Atlantic) and ODP Site 959 (Deep Ivorian Basin, eastern equatorial Atlantic). Our study reveals transitional individuals *Sphaeroidinellopsis disjuncta–Sphaeroidinellopsis kochi*, a speciation event never described in the previous literature. Those specimens are characterized by extreme morphological features such as elongated and sack-like final chambers, requiring amendments to the current classification and taxonomy of this genus.

Impact of Early Eocene climatic optimum on planktonic Foraminifera from the Pacific Ocean: Morozovellids marked decline and change in coiling direction

Giulia Filippi[1], Luciani Valeria[1], Roberta D'Onofrio[1], Thomas Westerhold[2], Bridget S. Wade[3], and Gerald R. Dickens[4]

[1]Department of Physics and Earth Sciences, Università degli Studi di Ferrara, Ferrara, Italy; [2]MARUM, Universität Bremen, Bremen, Germany; [3]Department of Earth Sciences, University College London, London, United Kindom; [4]Department of Geology, Trinity College Dublin, Dublin, Ireland

✉ giulia.filippi@edu.unife.it

We present here new insight on the relationship between early Eocene carbon-cycle changes, abundance and coiling direction of the trochospiral planktonic foraminiferal genus *Morozovella* from the Pacific Ocean (Shatsky Rise, Ocean Drilling Program Sites 1209, 1210). This location spans the Early Eocene climatic optimum (EECO; ~53–49 Ma), the interval when Earth surface temperatures and atmospheric pCO_2 reached their Caenozoic maximum (Zachos et al. 2001, Anagnostou et al. 2016, Inglis et al. 2020). The EECO impacted significantly the planktonic foraminiferal assemblages

of the Atlantic Ocean where a permanent marked decline in abundance, diversity, test-size, and change in coiling direction of the mixed-layer symbiotic bearing genus *Morozovella*, took place within the first ~600 kyrs of the EECO (Luciani et al. 2016, Luciani et al. 2017a, Luciani et al. 2017b, D'Onofrio et al. 2020, Luciani et al. 2021). Specifically, the morozovellid decline occurred close to the carbon isotope excursion (CIE) known as J event (~53 Ma; EECO beginning). A similar response is recorded from Sites 1209 and 1210 as *Morozovella* drops permanently its relative abundance up to one third at the top of the J event. At the Atlantic Ocean all the morphologically defined species of *Morozovella* display a dominant dextral coiling preference during the interval preceding the EECO but switched to sinistral coiling within ~200 kyrs after the CIE K/X event (~52.8 Ma). Comparably, the coiling direction of *Morozovella* at Shatsky Rise proved to be dominantly dextral below the EECO but then moved to dominantly sinistral, even though this flip occurred later (~200 kyrs) with respect to the Atlantic Ocean. Searching for the driven causes of the observed variations, our data clearly demonstrate their wide geographic, possibly global, character for which the link with the environmental perturbations of the EECO appears evident.

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How useful are calcareous nannofossils for dating rocks? An example in the Northern Calcareous Alps, Austria

Ángela Fraguas[1], Tim Cifer[2], and Špela Goričan[2]

[1]Depratment of Biology and Geology, Universidad Rey Juan Carlos, Madrid, Spain; [2]Paleontološki inštitut Ivana Rakovca, Ljubljana, Slovenia

✉ angela.fraguas@urjc.es

Calcareous nannofossils are considered one of the more useful tools for dating Lower Jurassic rocks, especially when there is not a precise calibration to ammonite zonations. This work gives new information about Lower Jurassic nannofossils in the Weitenhausgraben section (Mount Rettenstein, Austria), well-calibrated to radiolarian zones and the stable carbon isotope curve.

The studied section is made up of a 95 meters thick alternation of marls, grey siliceous limestones, and marly limestones. A total of 30 smear slides were prepared from the original samples. Semiquantitative analyses were performed for biostratigraphic observations (>2000 fields of view were analysed in each sample), using a Leica DMLP light microscope equipped with a Leica DFC 420 digital camera, at 1250× magnification. The abundance and degree of preservation of calcareous nannofossil assemblages, and the relative abundance of each species identified were analysed per smear slide.

A nannobiohorizon: The first occurrence of *Similiscutum cruciulus* has been identified in the sample RÖ451, marking the boundary between the NJ3 *Crepidolithus crassus*/NJ4 *Similiscutum cruciulus* calcareous nannofossil zones. This main event has been calibrated to the radiolarian data of Cifer et al. (2020) and to stable carbon isotopes. Based on the radiolarian assemblages, the samples between RÖ448 and RÖ453 belong to the *Canutus tipperi–Katroma clara* and *Zartus mostleri–Pseudoristola megaglobosa* zones, which correspond to the *Jamesoni* ammonite zone. This information fits with the first occurrence of *S. cruciulus*, considered a synchronous event around the world, taking place within the *Jamesoni* ammonite zone.

According to the stable carbon isotopes, radiolarians, and calcareous nannofossils, the Sinemurian/Pliensbachian transition is located between samples RÖ445 and RÖ446.

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Benthic Foraminifera oxygen and carbon isotopes offsets over the last 40 000 years as recorded in eastern tropical Pacific Site ODP 1242

Babette Hoogakker[1], Christopher Day[2], Sebastian Garrido[1], Tommaso Paoloni[1], Dharma Reyes Macaya[1], Melanie Leng[3], and Helge Winkelbauer[1]

[1]School of Energy, Geoscience, Infrastructure and Society, Heriot-Watt University, Edinburgh, UK; [2]Department of Earth Sciences, University of Oxford, Oxford, UK; [3]British Geological Survey, Keyworth, UK

✉ b.hoogakker@hw.ac.uk

Benthic Foraminifera oxygen and carbon isotopes are instrumental in our understanding of the past marine environment and understanding the earth system. It has long been known that offsets exist between benthic Foraminifera species, especially those with different depth habitats (e.g. epifaunal species with a preferred bottom water habitat living on top of sediments versus shallow and deep infaunal species that live in sediments). The assumption is often made that such offsets are constant with time and location. Previous studies of down-core stable isotope offsets between different benthic Foraminifera species, that cover glacial–interglacial timescales, are from the Atlantic & Indian Ocean and the South China Sea (Hoogakker et al. 2010), and the Southern Ocean (Gottschalk et al. 2016). The Pacific lacks an analysis of benthic Foraminifera species offsets over those timescales. Here we report on the oxygen and carbon isotope offsets of commonly occurring benthic Foraminifera at ODP Site 1242 in the eastern tropical Pacific over the last 40 000 years.

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Comparison of the calcareous nannofossils assemblages from different chalks for artworks provenance

Victory Jaques[1] and Katarína Holcová[1]

[1]Institute of Geology and Palaeontology, Univerzita Karlova, Prague, Czech Republic

✉ victory.jaques@gmail.com

Mesozoic chalk was used as priming for painted cultural heritage artefacts from the Gothic period (Švábenická 1994) up to the 18th century. The chalk is made of calcareous nannofossils which are used as proxies since the 90s due to their well-known palaeobiogeographic localities. The determination of the assemblages of calcareous nannofossils from the material used for cultural heritage artefacts is already applied by several researchers (Quinn 2017, Kędzierski and Kruk 2018).

We compared the assemblages of calcareous nannofossils from different localities known for their historical use (Rügen, Germany; Champagne, France; Bologna, Italy; and Belgium). We determined the calcareous nannofossils present in the chalks and counted the occurrence of each species. Variations between the species and their ratios such as *Arkhangelskiella* and *Watznaueria* was interesting. *Arkhangelskiella cymbiformis* is characterized to be in cool water when *Watznaueria barnesae* is in warm water (Huber and Watkins 1992). This kind of ratio helps for the provenance determination of the chalks which was the aim of this study and offer this comparison.

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Evolving ecology and morphology of Neogene planktonic Foraminifera

Grace Lamyman[1] and Tracy Aze[1]

[1]School of Earth and Environment, University of Leeds, Leeds, UK

✉ grace_l18@btinternet.com

Planktonic Foraminifera are marine microorganisms that have the most complete fossil record of the Caenozoic era. As such, they are widely employed for generating palaeoceanographic proxy data and for addressing evolutionary questions at the species level. In this work we use a high-resolution direct sampling approach to investigate the paired morphological and ecological evolution of a group enigmatic clavate planktonic Foraminifera; the *Globigerinella* and *Beella* lineages. This high-resolution analysis has allowed the speciation of *G. siphonifera*, *G. calida*, *G. adamsi*, and

B. megastoma and the extinction of *G. praesiphonifera* to be studied in detail. Paired individual-level morphometric and geochemical data have allowed for investigation into the relationships between chamber size, body size, and increasing ocean depth habitat through time.

Palynology of evaporites: Case studies and a bright future ahead

Gil Machado[1,2], Manuel Casas-Gallego[3], Houssine Boutarouine[4], Stanisław Burliga[5], and Paulo Fernandes[6]

[1]Chronosurveys Lda, Almada, Portugal; [2]Institute Dom Luiz, Universidade de Lisboa, Lisbon, Portugal; [3]Llandudno, United Kingdom; [4]Société de Sel de Mohammedia, Mohammedia, Morocco; [5]Institute of Geological Sciences, Uniwersytet Wrocławski, Wroclaw, Poland; [6]Faculty of Science and Technology, Universidade do Algarve, Faro, Portugal

✉ gil.machado@chronosurveys.com

Salt (*sensu* evaporites) is a critical element in many petroleum systems as it provides a seal, generates several types of traps, and influences thermal fluxes. Salt sedimentation age is commonly estimated based on the age of the underlying and overlying strata, from seismic and/or from well data. This allows a crude estimation of the sedimentation age, but mobile salt frequently complicates age interpretation. The usage of biostratigraphy in evaporitic sequences is surprisingly scarce and even more so in the oil industry. Palynology has been used successfully on several occasions, but the presumed difficulty in processing evaporite samples (the typical acid attack techniques are not suitable) may have deterred workers from using it more often. Palynology studies particulate organic matter contained in sedimentary rocks and allows determining sedimentation ages and characterizing palaeoenvironments. The required sample size varies, but usually 100 g of sediment or less are more than sufficient to obtain significant results, thus

cuttings, SWC, and core samples are suitable.

We have tested evaporites (rock salt and gypsum among others) and associated sediments (mostly mudstones) from five different locations, ranging from Miocene to Permian in age, both from tectonically deformed and undeformed evaporites. The samples are from outcrops, mine sections, and drill core sections.

The adapted processing technique is now standardized and the success rate is similar to non-evaporite samples. Productive sample characteristics (crystal size, colour, evaporite content) are now better understood and even higher success rates are expected in future analyses. Although results are variable, most samples are dominated by terrestrial-derived organic particles indicating restricted marine to fully terrestrial settings in most instances. The presence of phytoclasts (mostly vitrinite) allows for the quantitative determination of thermal maturity.

Planktonic Foraminifera records at Site IODP 1308 during the mid-Pleistocene transition (marine isotope stages 26 to 21).

***Maryline Mleneck-Vautravers*[1]**

[1]Department of Earth Sciences, University of Cambridge Godwin Laboratory, Cambride, UK

✉ mv217@cam.ac.uk

Although not a geological boundary the mid-Pleistocene transition (MPT) between 1.25 to 0.7 Myrs BP marks a crucial cooling step in the recent Earth climate history. During the MPT, the so-far dominant obliquity pacing (i.e. 41-kyrs cyclicity) captured in a wide range of palaeorecords became weaker in the absence of change in the astronomical forcing and resulted in icesheets growing for longer, hence glacials lasting longer, and becoming colder. Tzedakis et al. (2017), while proposing a rule to determine when a glacial termination occurs, highlighted that starting at the MPT some

summer insolation peaks attributable to obliquity were skipped in the record, therefore that the threshold for triggering a deglaciation of the icesheets was raised. Other hypotheses surrounding the MPT call for feedback in the climate system, through direct changes in icesheets size and/or locations (Kohler et al. 2020) or indirect one via regolith removal, either taking place in the Northern hemisphere or in Antarctica. Elderfield et al. (2012) linked these further to the gradual decline in atmospheric CO_2 during glacials as a forcing parameter.

Many studies point to marine isotope stages 24–22 (between 928 and 868 ka) as a crucial and peculiar glacial–interglacial–glacial cycle with three obliquity beats skipped (Tzedakis et al. 2017) and the sudden pronounced cooling of deep-water recorded by Elderfield et al. (2012).

Four-hundred planktonic Foraminifera faunal assemblages and ice-rafted detritus counts (150 µm) were obtained for Site IODP 1308 located in the middle North Atlantic *c.*50° N. They are used to highlight a sequence of events and try to draw some comparison with events having taken place during the last glacial and its termination at the same site. This new data set is presented on the age scale proposed by Hodell and Channell (2016) based on a detailed benthic $\delta^{18}O$ record measured on *Cibicides wuellestorfi*. The latter provides a scale for the evolution of the ice volume.

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Finite Element Analysis: A method to assess the impact of climate change on the structural integrity of benthic Foraminifera.

James Mulqueeney[1,2,3], Leanne Melbourne[4,1], Danna Titelboim[5,1], and Suman Sarkar[1]

[1]Department of Earth Sciences, University of Bristol, Bristol, UK; [2]Department pf Earth and Ocean Sciences, University of Southampton, Southampton, UK; [3]Department of Life Sciences, Natural History Museum London, London, UK; [4]MAT, American Museum of Natural History, New York (NY), USA; [5]Department of Earth Sciences, University of Oxford, Oxford, UK

✉ jamesmulqueeney611@gmail.com

Benthic Foraminifera are a group of calcifying marine organisms that play a significant role in global carbonate production. During periods of environmental change, the morphology of these organisms is known to be affected. Such changes may lead to the production of weakened forms, leaving benthic Foraminifera more susceptible to breakage through predation or exposure to wave action. Finite Element Analysis is a useful mathematical technique that allows us to assess structural integrity within biological organisms. Here, simple finite element models are used to assess how the morphology of benthic Foraminifera is affected during periods of climate change and how they impact overall structural integrity. Assessment of these morphological changes focused on the creation of simple 3 D geometric models, based on 2 D images, that can easily be altered. To assess the reliability of these models, they were compared to biologically accurate 3 D geometric models of benthic Foraminifera which were generated from computed tomography scans. The results showed that the simple models were capable of distinguishing differences in mechanical robustness. These simple models were then altered in alignment with morphological changes observed in the fossil record of the Palaeocene–Eocene thermal maximum (PETM). The results show that species-specific

morphological changes that occurred across the PETM led to a weakening of structural integrity. This suggests that, under future climate change, certain species of benthic Foraminifera may produce mechanically weaker tests, making it harder to withstand physical pressures. This could, in turn, lead to a lower diversity and abundance of benthic Foraminifera.

Defining reference conditions and assessing anthropogenic effect on ecosystem quality in transitional waters, using benthic foraminiferal indices

Phoebe O'Brien[1] and Irina Polovodova Asteman[1]

[1]Marine Sciences, Göteborgs universitet, Göteborg, Sweden

✉ phoebe.obrien@gu.se

Transitional waters, like fjords, estuaries and rias, lie at the interface between terrestrial and marine environments. They provide a range of important ecosystem services, including but not limited to transport, food and aesthetic value. Due to such benefits these ecosystems have been targeted for human dwelling for centuries and have been disproportionally impacted by anthropogenic forcing, meaning that today none can be regarded as 'pristine'. Hence there is a lack of reliable present-day baseline conditions with which to compare ecological quality. The Holocene–Anthropocene boundary is highly contentious and currently still unformalized, however the Industrial revolution and the 'Great Acceleration' standout as most pronounced and globally synchronous signals. Investigation of the transition from pristine condition to anthropogenically impacted is key in better understanding this interval. Using biotic indices derived from benthic foraminiferal microfossils in marine sediment record, we are able to retroactively reconstruct, in high resolution, the ecological quality of fjord environments, prior, throughout and beyond the industrial revolution. Providing a reliable benchmark for ecosystem quality assessments (ECOQS) and

characterizing the magnitude and rate of environmental changes throughout this boundary period. This research is based on a case study from Idefjord (Sweden/Norway), which was exposed to a heavy pollution by pulp and paper industry in the past. Using both traditional morphospecies-based approach and molecular (eDNA and aDNA) methods to estimate foraminiferal diversity and pollutant (TOC and metal data) from dated sediment cores we aim to define baseline conditions, delineate recovery cycle, and align those with local environmental legislation, to better understand the effect of mitigative measures and inform future action.

Palaeoceanographic changes registered by planktonic Foraminifera across the Cenomanian–Turonian OAE 2 at high latitudes (IODP U1516, SE Indian Ocean)

Maria Rose Petrizzo[1], David K. Watkins[2], Kenneth G. MacLeod[3], Takashi Hasegawa[4], Brian T. Huber[5], Sietske J. Batenburg[6], and Tomonori Kato[7]

[1]Department of Earth Sciences 'A. Desio', Università degli Studi di Milano, Milan, Italy; [2]Department of Earth and Atmospheric Sciences, University of Nebraska, Lincoln (NE), USA; [3]Department of Geological Sciences, University of Missouri—Columbia, Columbia (MO), USA; [4]Department of Earth Sciences, Kanazawa University, Kanazawa, Japan; [5]National Museum of Natural History, Smithsonian Institution, Washington, D.C., USA; [6]Department of Earth and Ocean Dynamics, Universitat de Barcelona, Barcelona, Spain; [7]Graduate School of Natural Science and Engineering, Kanazawa University, Kanazawa, Japan

✉ mrose.petrizzo@unimi.it

Planktonic Foraminifera, benthic foraminiferal, and radiolaria distributions combined with $\delta^{13}C$ and $\delta^{18}O$ measurements of both bulk carbonate and Foraminifera provide clues concerning the palaeoceanographic changes across the Cenomanian–Turonian boundary interval and the oceanic anoxic event 2 (OAE 2) at southern high latitudes. Data are from the Integrated Ocean Discovery Program (IODP) Site U1516 in the Mentelle Basin

(Indian Ocean, SW Australia) that was located at 60°–62° S palaeolatitude. It is the first high latitude locality in the Southern Hemisphere where planktonic Foraminifera are consistently recorded across OAE 2. The correlation between the stable isotopic data and the integrated calcareous plankton biostratigraphy with the Eastbourne (England) section indicate that a complete record of OAE 2 at Site U1516 was recovered.

Below and in the lower part of OAE 2, the planktonic foraminiferal assemblages are dominated by small-sized opportunistic species and radiolaria indicating a dominantly eutrophic regime. Above the onset of OAE 2, a trough in the δ^{13}C profile coinciding with a δ^{18}O increase may correspond to the Plenus cold event as observed at low latitudes, although no evidence of cooling is registered in the microfossil assemblages. The middle part of OAE 2 is masked by absence of carbonate, by the highest TOC values, and high biogenic silica indicating this interval corresponded to a time of highly stressed eutrophic conditions with possible shoaling of the calcite compensation depth. Toward the top of OAE 2, data reveal a palaeoceanographic setting still affected by eutrophy likely related to enhanced input of nutrients. In this interval are also recorded the highest sea surface water palaeotemperatures values of 20–23 °C based on δ^{18}O values of foraminiferal shells. After the OAE 2 event in the Turonian, stable conditions in the water column were established as evidenced by a diverse planktonic foraminiferal assemblage with different species occupying separate ecological niches.

Size matters at the MSC-onset: Narrative of an adaptation

Francesco Pilade[1], Alan Maria Mancini[1], Francesca Lozar[1], and Rocco Gennari[1]

[1]Department of Earth Sciences, Università degli Studi di Torino, Turin, Italy

✉ francesco.pilade@unito.it

The Messinian Salinity Crisis (MSC) was a dramatic geological event in the Mediterranean Basin that started at 5.97 Ma, leading to the deposition of huge volumes of evaporites. The causes that triggered the MSC are still debated in the scientific community. The Perales composite section of the Sorbas Basin (SE Spain) records the palaeoceanographic evolution towards the crisis from 7.2 to 5.97 Ma (pre-evaporitic phase), when the Mediterranean became more restricted and its climatic sensitivity was enhanced.

We quantitatively analysed benthic foraminifers of the uppermost 12 cycles of the Perales section in order to shed light on the cyclical bottom water changes that preceded the MSC.

Variation in orbital parameters drove the deposition of lithological cycles composed of sapropel, marl, and diatomite layers that are characterized by oligotypic microfossil assemblages related to variation of insolation and eccentricity.

Our results show the dominance of the stress-tolerant *Bolivina*, *Bulimina*, and *Rectuvigerina* groups in response to different diet preferences, different modalities of organic matter exported to the seafloor, and to water column stratification. Morphometric analyses on *Bolivina* gr. show a decrease in size related to prolonged stratification-driven anoxic sea floor during insolation maxima. We speculate that these cyclical size reductions could be linked to different electronic acceptor availability (O_2 and NO_3^-), as observed in the modern oxygen minimum zone.

In the upper part of the section, the disappearance of the *Rectuvigerina* gr. suggests enhanced stress at the seafloor approaching to the MSC, possible driven by a further restriction of the circulation.

Microbioerosion on the Late Triassic to Middle Jurassic Foraminfera from the Dachstein limestones in the Northern Calcareous Alps, Austria

Matic Rifl[1], Petra Lukeneder[2], Alexander Lukeneder[2], Luka Gale[3,4], and Katarína Holcová[1]

[1]Institute of Geology and Palaeontology, Univerzita Karlova, Prague, Czech Republic; [2]Department of Geology and Palaeontology, Naturhistorisches Museum Wien, Vienna, Austria; [3]Department of Geology, Univerza v Ljubljani, Ljubljana, Slovenia; [4]Geološki zavod Slovenije, Ljubljana, Slovenia

✉ riflm@natur.cuni.cz

Microborings are the most common evidence of microbial activity in the ancient oceans that contribute to the destruction of carbonate rocks returning their material to the biogeochemical cycle. The distribution of the microboring communities may exhibit characteristic zonal patterns controlled by various palaeoenvironmental factors, such as water dynamics, sedimentation rate and consequently the time available for colonization.

The aim of our study was to investigate microbioerosion on benthic Foraminifera spanning from the upper Rhaetian to the upper Sinemurian carbonates in the Northern Calcareous Alps. We have described and evaluated the relative abundances of microborings preserved at the surface of foraminiferal tests, as well as of dendritic structures penetrating into the tests. The samples were taken from the Tannscharte and the Fahrenberg sections, located in the Schneeberg Syncline within the High Bajuvaric unit. In the two sections, the 'Upper Rhaetian limestone' ('Oberrhät limestone') of the Kössen formation is unconformably overlain by the crinoidal

limestone of the Hierlatz type, followed by the Adnet formation, and finally the Allgäu formation. Palaeoenvironmentally, the formations represent an extensive shallow marine carbonate platform, bordered to the southeast by an extensive lagoon with fringing reefs. Altogether, microborings from 111 thin sections were investigated.

Preliminary results show very common microborings occurring on foraminiferal tests in the Hierlatz limestone where lagenids determined as ?*Protonodosaria* or ?*Pseudonodosaria* sp. contain mostly branched tubular microborings with numerous entrances into interior of the test. In the Adnet formation, Foraminifera *Involutina liassica* (Jones) is microbored less frequently. The tests mostly exhibit deeply penetrating branched tubular networks of microborings, which seem to be concentrated among the papillae. In the Kössen formation, despite a rich foraminferal assemblage, microborings seldom occur.

Late Miocene to Pleistocene calcareous nannofossil events from the northeast Indian Ocean

Lopamudra Roy[1,2], Amit K. Ghosh[1], Ajoy Kumar Bhaumik[3], and Sarajit Sensarma[2]

[1]Marine Micropalaeontology, Birbal Sahni Institute of Palaeosciences, Lucknow, India; [2]Centre of Advanced Study in Geology, University of Lucknow, Lucknow, India; [3]Applied Geology, Indian Institute of Technology (Indian School of Mines), Dhanbad, India

✉ lopamudraroy15@gmail.com

Calcareous nannofossils, significant oceanic primary producers, are used as a significant tool in biostratigraphy for precise age determination of the oceanic sediments both regionally and globally. Because of the wide geographical range and short geological range of calcareous nannofossils, they are widely used as biostratigraphic markers. Different biozones or

biostratigraphic events with respect to the geological time scale can be determined on the basis of the first and last occurrences (FO and LO) of marker nannofossils. In the present study, a detailed analysis of the calcareous nannofossils has been conducted on a sediment core drilled in the northeast Indian Ocean during the National Gas Hydrate Program of India Expedition-01 (NGHP-01-17A). The overall preservation potential of the nannofossils is moderate to good. Owing to the FOs of *Amaurolithus primus*, *Nikilithus amplificus*, *Ceratolithus cristatus*, and *Gephyrocapsa oceanica* and LOs of *Discoaster quinqueramus*, *Discoaster pentaradiatus*, and *Pseudoemiliania lacunosa*, the studied sequence of the core has been dated as late Miocene to Pleistocene. The calcareous nannofossil assemblages of the present study have been correlated with the known assemblages of this time interval from DSDP, ODP, and IODP expeditions and onshore sediments of the Indian Ocean as well as the equatorial Pacific Ocean. To estimate the sedimentation rate during this time interval, an age–depth model has been proposed based on the significant events of calcareous nannofossils.

Late Miocene calcareous nannofossils from Neil Island, northeast India Ocean

Stuti Saxena[1], Arindam Chakraborty[1], and Amit K. Ghosh[1]

[1]Marine Micropalaeontology, Birbal Sahni Institute of Palaeosciences, Lucknow, India

✉ saxena06.stuti@gmail.com

The present study on calcareous nannofossils has been carried out from the samples collected from an outcrop (11° 49' 24.9" N, 93° 3' 34.3" E) on Neil Island (Sitapur village) of the Andaman and Nicobar basins. All the samples from the Sitapur village section on Neil Island yielded common to abundant, well preserved nannofossils. The assemblage is dominated by

Helicosphaera carteri, small reticulofenestrids (*Reticulofenestra haqii* and *R. minuta*), and *Spenolithus moriformis*. Other associated forms include common occurrence of *Calcidiscus leptoporus*, *C. macintyrei*, *Coccoloithus pelagicus*, *Discoaster brouweri*, *D. exilis*, *D. loeblichii*, *D. quinqueramus*, *Helicosphaera sellii*, *Pontosphaera multipora*, *P. discopora*, *Sphenolithus abies*, and *Umbilicosphaera rotula*. Amongst the lineages of asteroliths, discoasters are important because of their higher diversity and relative quantitative prominence in the tropical as well as subtropical provinces. On the basis of the presence of index nannofossils, viz. *Discoaster quinqueramus*, the section may be assigned to the *Discoaster quinqueramus* zone, i.e. NN11 zone of late Miocene (Tortonian) age. Higher abundance of small reticulofenestrids and sphenoliths are indicative of warm environment. During the late Miocene it has been observed that there is significant reduction in size of reticulofenestrids that indicates eutrophic, nutrient rich condition. Higher abundance of small reticulofenestrids indicates higher productivity. Thus, the dominance of small reticulofenestrids accompanied by the presence of characteristic upwelling diatom taxa, viz. *Thalassiothrix longissima* and *Thalassionema nitzschoides* in the studied section, points towards upwelling condition. Relative abundance of both diatoms and calcareous nannofossils also signifies that there was biogenic bloom during late Miocene.

Planktonic Foraminifera size variation analysis: How choosing the wrong descriptor can lead to wrong assumptions

Jaime Yesid Suárez-Ibarra[1], Ingrid Vieira[2], María Alejandra Gómez Pivel[2], and Manuel F. G. Weinkauf[1]

[1]Institute of Geology and Palaeontology, Univerzita Karlova, Prague, Czech Republic; [2]Department of Palaeontology and Stratigraphy, Universidade Federal do Rio Grande

do Sul, Porto Alegre, Brazil

✉ jysuarezibarra@gmail.com

Planktonic foraminiferal shell size is a common measurement in ecological and oceanographic studies. Nevertheless, no common agreement for a population-wide size descriptor exists in the literature, with mean or median size and benchmark sizes of a defined percentile of the foraminiferal assemblages (e.g. mean of the largest 5 % of the population, S_{95}) being used interchangeably. For drastic environmental changes that alter entire planktonic Foraminifera assemblage sizes (e.g. Aptian–Albian, K/Pg boundary), any descriptor is capable to capture these changes. Smaller palaeoenvironmental changes, however, can lead to subtle shell-size changes not all shell size descriptors would indicate. Here, we explore a new method for an integrated shell-size metric and demonstrate how the use of arbitrary descriptors can lead to different conclusions. We analysed planktonic Foraminifera shell sizes of six species from a sediment core retrieved from the western South Atlantic. Cross-sectional area measurements of foraminiferal shells were analysed and mean, median, 1st and 3rd quartiles, and 95th percentile shell sizes were extracted per species and sample. These descriptors were subjected to a principal component analysis and the scores of the first principal component were used as a new, integrated shell size measurement (S_{PC1}). The correlation between S_{PC1} and palaeoenvironmental variables (temperature, productivity, and dissolution) was tested. For five of the six studied species, environmental correlations using only S_{95} would have been underestimated: For instance, in *Globoconella inflata*, no correlations were found using S_{95}, implying that none of the analysed environmental parameters controlled the planktonic Foraminifera size variations. In contrast, S_{PC1} of *G. inflata* showed a significant correlation with three palaeoproductivity proxies. We suggest S_{PC1} as standard shell size measurement in the future, that is able to better capture the entirety of shell size changes.

Foraminiferal organic linings: Emerging phylogenetic trends and research challenges

Jaroslaw Tyszka[1], Karolina Godos[1], Jan Goleń[1], and Wiesława Radmacher[1]

[1]Institute of Geological Sciences, Polska Akademia Nauk, Krakow, Poland

✉ ndtyszka@cyf-kr.edu.pl

Foraminifera leave in the sedimentary rocks two types of fossil records represented by mineralized shells (tests) and their organic linings. Although both types of microfossils require different preparation methodologies, they should be treated complementary as they come from the same source of specimens represented by organo–mineral shells. Unfortunately, the fossil archive of acid resistant organic linings is highly fragmentary, and the overall foraminiferal record is highly biased towards mineral shells. Our meta-analysis of the overall published record of linings from the Palaeozoic till today indicates that nearly all foraminiferal linings have globular chambers that show minimized distances between successive foramina/apertures. These two morphological features classify them into the Globothalamea class (*sensu* Pawłowski et al. 2013). The question therefore is why there is nearly no record of fossil linings that belong to other foraminiferal classes. Do all Foraminifera produce organic linings? Are they compositionally and structurally similar? What is their taphonomic potential? If foraminiferal linings are phylogenetically significant, they might be involved in specific functions associated with different groups and their morphogenetic and biomineralization patterns. All these questions encourage our interdisciplinary investigations and set crucial research targets of the new project. The latest overview of knowledge on foraminiferal organic linings is reviewed by Tyszka et al. (2021). The ForamL 1.2 database (Godos et al. 2021) can be downloaded under CC-BY-NC-SA from http://eforams.org/img_auth.php/6/69/ForamL_ver.1.2-2021.pdf. The presented research received support from the Polish National Science Centre —project

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Preliminary results from large-scale culturing experiments on *N. pachyderma*: Development of a proxy toolbox for polar ocean surface hydrography

Adele Westgård[1], Julie Meilland[2], Thomas B. Chalk[1,3], Andy J. Milton[3], Gavin L. Foster[3], Michael Kučera[2], and Mohamed M. Ezat[1]

[1]CAGE, Universitetet i Tromsø—Norges arktiske universitet, Tromsø, Norway; [2]MARUM, Universität Bremen, Bremen, Germany; [3]National Oceanography Centre Southampton, University of Southampton, Southampton, England

✉ adele.westgard@uit.no

Ongoing changes in the Arctic cryosphere and ocean circulation have significant implications for regional climate and beyond. Past records of cryosphere–ocean–climate links provide invaluable insights to better constrain future climate scenarios. However, a lack of robust proxy calibrations remains a challenge in studying Arctic Ocean palaeoceanography. To this end, we have conducted culturing experiments on the polar species *Neogloboquadrina pachyderma* to establish a proxy toolbox for surface ocean hydrography and freshwater dynamics at high latitudes.

More than 1000 healthy specimens of *N. pachyderma* were picked from plankton samples from the Greenland Sea (74° N, 2° E). These were placed into twelve treatments which were determined relative to field conditions (ambient) and a realistic range of past and future conditions. Salinity ranging from 30 to 37.5, pH from 7.7 to 8.3, temperature from 2 to 7 °C, as well as variable barium concentrations.

We observed calcification of new chambers and addition of crust in all treatments. Growth rate was not linear, with extended periods without apparent calcification. Overall, we observed low mortality across all treatments prior to ending the experiments. A significant number of specimens, initially described as dead (e.g. white cytoplasm, absent rhizopodial activity), recovered (colourful cytoplasm, extensive rhizopodial network, feeding etc.) in subsequent weeks testifying their ability to adapt to and/or recover from unsuitable conditions. We also observed several events of asexual reproduction. These observations suggest that *N. pachyderma* adapt to, and calcify at a wide range of conditions, which has implications for the species' response to ongoing ocean warming and acidification, as well as for future studies aiming to culture *N. pachyderma*.

We are in the process of analysing elemental ratios (e.g. B/Ca, Na/Ca, Mg/Ca, Ba/Ca) in the culture-grown calcite of *N. pachyderma* using LA-ICP-MS, which will also be discussed.

Caenozoic climate regime drove spatial patterns in speciation and dispersal dynamics of planktonic Foraminifera

Adam Woodhouse[1,2], Alex Dunhill[1], Erin Saupe[3], Paul Wignall[1], Isabel Fenton[3], and Tracy Aze[1]

[1]School of Earth and Environment, University of Leeds, Leeds, UK; [2]Institute for Geophysics, University of Texas at Austin, Austin (TX), USA; [3]Department of Earth Science, University

of Oxford, Oxford, UK

✉ adam.woodhouse@austin.utexas.edu

Global marine ecosystems are currently experiencing the most significant environmental change of the past 66 million years. Investigating how speciation and extinction patterns responded to climatic changes in the geological past provides a benchmark for assessing potential negative impacts in the future.

The marine microfossil record of Caenozoic planktonic Foraminifera is the most complete and phylogenetically resolved of any group of organisms available for study. As such, the novel planktonic foraminiferal occurrence database, Triton, is used to assess the biogeographic variability of this group through geological time, examining trends in speciation and extinction locales. It is found that palaeolatitudes of speciation and extinction varied with regard to the underlying global climate conditions of the time. The Greenhouse regime of the early Palaeogene was dominated by extratropical speciation cradles which, as global temperature declined, were progressively complimented by lower latitude speciation. This tropical speciation cradle now acts as the primary marine cradle in the cooler climates of the Icehouse regime.

The global biogeographic patterns observed within this study reveal fundamental elements of marine macroevolutionary dynamics through geological time, suggesting that the location of taxon speciation and extinction is driven primary by the underlying global temperature. As anthropogenic forcing pushes global climate towards a state analogous to the Greenhouse world of the Palaeogene, marine speciation and biodiversity dynamics will likely migrate to higher latitudes, altering future marine ecosystem function.

Using silicon isotopes and diatom assemblages to assess nutrient cycling in the Bering Sea during the mid-Pleistocene transition

Savannah Worne[1], George Swann[2], Sev Kender[3], Jack Lacey[1], and Melanie Leng[1,2]

[1]National Environmental Isotope Facility, British Geological Survey, Nottingham, UK; [2]Centre for Environmental Geochemistry, University of Nottingham, Nottingham, UK; [3]Camborne School of Mines, University of Exeter, Cornwall, UK

✉ savw@bgs.ac.uk

The rate of deep-ocean carbon burial is considered important for modulating glacial–interglacial atmospheric CO_2 concentrations and global climate during the Quaternary. It has been suggested that glacial iron fertilization and increased efficiency of the biological pump in the Southern Ocean since the mid-Pleistocene transition (MPT) shift to 100-kyr glacial cycles was key in lowering atmospheric pCO_2 and facilitating rapid land ice accumulation. There is growing evidence that a similar mechanism may have existed in the subarctic Pacific Ocean, although this has not yet been assessed during the MPT. Here, the silicon isotope composition of diatoms ($\delta^{30}Si_{diatom}$) from the Bering Sea upwelling region is used to assess the role of nutrient cycling on the subarctic Pacific biological pump during the MPT. Results show that during and after the '900-ka-event', the green belt was characterized by low silicic acid utilisation but high supply, coincident with the dominance of diatom resting spores. This suggested that as nutrient upwelling was suppressed following expansion of sea ice and glacial North Pacific intermediate water (GNPIW), opal remineralization became the dominant form of silicic acid supply. However, preferential preservation and higher cellular carbon content of diatom resting spores, as well as increased supply of iron from expanded sea ice, may have sustained the net efficiency of the Bering Sea biological through the MPT. Remnant iron and remineralized silicic acid may also have propagated into the lower subarctic Pacific Ocean

through GNPIW, aiding a regionally efficient biological pump at 900 ka and during post-MPT glacials.

Conflicting priorities and concepts in nannoplankton taxonomy

***Jeremy Young*[1]**

[1]Department of Earth Sciences, University College London, London, UK

✉ jeremy.young@ucl.ac.uk

Linnean taxonomy is not always the most widely regarded of scientific achievements but actually it is quite awesome. The same system of nomenclature is applied across the extraordinary range of global biodiversity—notwithstanding slight differences between the zoological and botanical codes. Equally the same system is used across the globe and in every language. In information technology terms this makes it a uniquely rich and widely applied name-space. Nonetheless not only is the system incomplete but also there are conflicts and controversies as to how it should be applied, not least because the same system is applied by a wide range of scientists with a wide range of methods, priorities, and objectives. Cataloguing and indexing taxonomic usage inevitably brings such conflicts into focus and in my case is increasingly a cause of problem and difficult decisions in developing the Nannotax database (this also applies with the pforams@mikrotax database but less acutely since it is more heavily based on published monographs). In particular, two sets of conflicting views are important and should be understood by all micropalaeontologists—those of phylogeneticists vs palaeontologists and of palaeoceanographers vs biostratigraphers. This talk will discuss some active conflicts of opinion in these areas within nannoplankton research.

Part III

Annual Conference 2021—Posters

Calcareous nannofossil biostratigraphy of the 'Dan-01' well, offshore Niger Delta, south-South Nigeria.

Mayowa Ajayi[1] and Peter Ola[1]

[1]Applied Geology, Federal University of Technology Akure, Akure, Nigeria

✉ mayowaajayi07@gmail.com

A biostratigraphy work using calcareous nannofossils was carried out on a section (4210 feet (1283.5 m)–5410 feet (1649.3 m)) of well 'Dan-01' located offshore Niger Delta, Nigeria. Lithological descriptions of the samples were done using a stereo-binocular microscope. Forty-one ditch cutting samples retrieved from the section studied were prepared using simple smear method and analysed for their calcareous nannofossil contents using an Olympus light microscope in both plane-polarized and cross-polarized light at 1000× magnification with immersion oil. The lithostratigraphic descriptions of the samples showed alternation sequence of shale and sand with sand beds predominating. This suggests that the section studied belongs to the upper Agbada formation.

The calcareous nannofossil zones established are the NN5 zone, characterized by the occurrence of *Sphenolithus heteromorphus* and dated Middle Miocene; and the NN4 zone, characterized by the co-occurrence of *Helicosphaera ampliaperta* and *Sphenolithus heteromorphus* with the ACME of *Discoaster deflandrei* and *Helicosphaera ampliaperta* and dated Early Miocene.

With these three condensed sections, likely locations of the 15.0 Ma maximum flooding surface (MFS), 16.0 Ma MFS, and 17.4 Ma MFS, respectively, were identified in the section studied.

Biostratigraphical and palaeoecological evaluation of planktonic and benthic Foraminifera across the Albian–Cenomanian transition

Tímea Aranyi[1] and József Pálfy[2]

[1]Department of Geology, Eötvös Loránd Tudományegyetem, Budapest, Hungary; [2]Department of Geology, MTA-MTM-ELTE Paleontológiai Kutatócsoport, Budapest, Hungary

✉ timea.aranyi3@gmail.com

The climatic and environmental conditions of the Cretaceous period are known through the study of deep-sea drilling cores from today's oceans, but the history of the Tethys ocean basin holds further exciting research questions. Upper Albian sediments are found in sections in Hungary, so we investigated here the Breistroffer event (OAE1d). The Jásd-42 borehole penetrates a 473 m thick section of the Pénzeskút Marl formation, its dominant lithology is marlstone, with few limestone and dolomite gravel interbeds. The stratigraphic range of the Pénzeskút formation is known from previous studies as Upper Albian–Lower Cenomanian, but because of the need for taxonomic revision of Foraminifera, it has become possible to refine the planktonic Foraminifera biozonation. In addition, quantitative analysis of benthic Foraminifera assemblages has been performed using morphotype analysis, calculation of the benthic Foraminiferal oxygen index, and diversity indices. The low latitude planktonic foraminiferal biozonation was applied and led to the recognition of the following bioevents and biostratigraphic results. The combined presence of *Thalmanninella appenninica* and *Planomalina buxtorfi* in the lowermost samples indicates a Late Albian age. The first occurrence of *Thalmanninella globotruncanoides* can be detected, which is the primary criterion for defining the Albian–Cenomanian boundary. The most common benthic Foraminifera genera (constituting ~90 % of the fauna) are *Gyroidinoides*, *Lenticulina*, *Gavelinella*, *Osangularia*, *Epistomina*, *Praebulimina*, *Tritaxia*, and *Quinqueloculina*. From other Cretaceous sites, these taxa are often reported from samples that

preceded the formation of black shale. Miliolinids are almost completely absent from the lower part of the sequence, but in other samples they make up to 10 % of the benthic Foraminifera fauna. Traditionally, they were considered as oxic environmental indicators, but some recent and Cretaceous studies have shown that certain *Quinqueloculina* species can tolerate reduced oxygen content.

Morphological variation in the extant coccolithophore genus *Palusphaera* (Prymnesiophyceae)

Odysseus Archontikis[1] and Jeremy Young[2]

[1]Department of Earth Sciences, University of Oxford, Oxford, UK; [2]Department of Earth Sciences, University College London, London, UK

✉ odysseas.archontikis@univ.ox.ac.uk

The genus *Palusphaera* Lecal–Schlauder emend. Norris is a distinctive modern coccolithophore that accommodates monomorphic, monothecate coccospheres with one type of spine-bearing heterococcoliths. Having examined a set of scanning electron microscopy images from our collections, we were able to demonstrate that four distinct species of *Palusphaera* exist in the modern oceans, including the type species *Palusphaera vandelii*, an informally proposed form, *Palusphaera* sp. 1 type *robusta* (Cros and Fortuño 2002, Young et al. 2003), and a newly discovered distinctive morphotype (Archontikis and Young 2021). Biometric analyses and observations on the morphologies of numerous *P. vandelii* specimens revealed the existence of a further form, and its commonly distinguished coccolith morphotypes are therefore taxonomically separated from *Palusphaera vandelii* and established as a discrete species.

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Foraminiferal associations of Vienna Basin based on the borehole MZ 102

Jaroslava Babejová-Kmecová[1], Natália Hlavatá Hudácková[1], and Ivana Plašienková[1]

[1]Department of Geology and Palaeontology, Univerzita Komenského v Bratislave, Bratislava, Slovakia

✉ kmecova45@uniba.sk

Foraminifera have a great sensitivity to environmental changes and quick phylogenetic response. Their fossils can be used in palaeoenvironment interpretation and biostratigraphic dating. Our samples come from the borehole MZ 102, collected near Malacky (Western Slovakia) in the Záhorská nížina plain (Vienna Basin). The aims of the study are: the palaeoenvironmental interpretation of the western part of the Vienna Basin during the middle Miocene, the determination of foraminiferal change at the Badenian/Sarmatian boundary, and the determination of the relation between

the foraminiferal morphogroups, ecologic factors, and diversity. The studied borehole contains several sediment levels with a predominance of miliolids. The core sample consist of siltstones and intercalated sandstones. The Foraminifera assemblages were determined into species and intergraded into morphological epiphytes groups (Langer 1988) and infauna (Murray 2009). The studied part of the cores was characterized by specific foraminiferal associations and species. Different amounts and types of epyphytes were observed. Two cores contained planktonic foraminiferal species (*Tenuitella munda*) which are representing the upper Badenian, acme-zone *Tenuitellinata* (Filipescu and Silye 2008). The Sarmatian was determined trough the first occurrence of the Sarmatian species. A deep low-oxygen environment was determined by the presence of epiphytes and planktonic species. Miliolid associations are suggesting a hypersaline environment and shallow bay areas.

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Mg/Ca palaeotemperatures at the Early Eocene climatic optimum from southern Atlantic Site 1263: Link to changes in planktonic foraminiferal assemblages?

Antonella Gandolfi[1], Valeria Luciani[1], Roberta D'Onofrio[1], Massimo Tiepolo[2], and Enrico Cannaò[2]

[1]Department of Physics and Earth Sciences, Università degli Studi di Ferrara, Ferrara, Italy;
[2]Department of Earth Sciences 'A. Desio', Università degli Studi di Milano, Milan, Italy

✉ antonella.gandolfi@edu.unife.it

The Early Eocene climatic optimum (EECO; ~53–49 Ma), that records the peak of Caenozoic warmth and CO_2 pressure (e.g. Zachos et al. 2001, Anagnostou et al. 2016, Inglis et al. 2020), induced climatic and palaeoceanographic changes that significantly impacted planktonic foraminiferal assemblages. The main change is the permanent marked decline in abundance, diversity, and test-size of the mixed-layer symbiotic bearing genus *Morozovella*, coupled with the increase of *Acarinina* that occurred at the basal EECO (Luciani et al. 2016, Luciani et al. 2017a, Luciani et al. 2017b, D'Onofrio et al. 2020). At the Southern Atlantic Site 1263, a drop in abundance of subbotinids and chiloguembelinids is also recorded within the EECO (Luciani et al. 2017b). Even though a link between the aforementioned modifications and the EECO perturbation appears evident, the driving causes of the recorded modifications are still unknown. Searching for possible explanations, we performed Mg/Ca derived palaeotemperatures from Site 1263 through laser ablation (LA)-ICP-MS. Preliminary Mg/Ca data reveal that *Morozovella crater* and *M. subbotinae* record a greater warming across the EECO with respect to *Acarinina coalingensis* and *A. soldadoensis*. We hypothesize that the higher rise in temperature recorded by morozovellids may have reduced their symbiotic relationship that can represent a reason for their reduction in abundance and size, even though other potential stressors such as pH decrease should be explored. Although the exact causes of photosymbiont bleaching can be manifold,

increased temperature is considered a primary factor of bleaching in present tropical larger benthic Foraminifera (e.g. Hallock 2000). We record from Site 1263 also a thermocline temperature increase that may justify the drop in abundance of cold-indices subbotinids and chiloguembelinids at the EECO.

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Global database of foraminiferal organic linings

Karolina Godos[1], Jarosław Tyszka[1], Wiesława Radmacher[1], and Jan Goleń[1]

[1]Institute of Geological Sciences, Polska Akademia Nauk, Krakow, Poland

✉ k.kobos@ingpan.krakow.pl

We present a new database of foraminiferal organic linings (FOLS) based on the published data. The purpose of this data collection is to increase the scientific understanding of the origin, taphonomy, and phylogenetic patterns of these fossilized organic Foraminifera structures. The main principle of data collection was the preparation method based on palynological procedures used by authors of original papers. The procedures involved: Treating the samples with hydrochloric acid (HCl) to remove carbonates followed by hydrofluoric acid (HF) to remove silicates, and then sieving through 10/15/20 µm-mesh screens. In most of the original papers, palynological slides were used to identify palynomorphs under optical microscopes equipped with cameras. Some authors applied scanning electron microscopes as a complementary documentation method. Our extensive survey of existing literature resulted in the collection of 155 scientific reports that illustrate 614 organic Foraminifera linings. All the linings were assigned to the groups of Foraminifera according to the classification of Pawłowski et al. (2013) and chamber growth patterns. The database consists of three tables covering the entire Phanerozoic broken down into erathems/eras and systems/periods. The results of work on the database revealed the dominant presence of organic linings from the Globothalamea class. The latest overview of knowledge about FOLS is reviewed by Tyszka et al. (2021). The ForamL 1.2 database (Godos et al. 2021) can be downloaded under CC-BY-NC-SA from http://eforams.org/img_auth.php/6/69/ForamL_ver.1.2-2021.pdf. The database will be further supplemented with available records of organic Foraminifera

litter, therefore any missing or new specimens from published and unpublished FOLs is welcome. The presented research received support from the Polish National Science Centre—project DEC-2020/37/B/ST10/01953.

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Reconstruction of the Upper Pleistocene–Holocene paleoenvironment in the western Mediterranean (Alboran Sea) based on dinoflagellate cysts records

Jihad Rachid[1], Touria Hssaida[1], and Naima Hamoumi[2]

[1]Department of Geology, Hassan II University of Casablanca, Casablanca, Morocco; [2]Department of Geology, Mohammed V University, Rabat, Morocco

✉ jihadrachid237@gmail.com

A qualitative (statistical techniques) and quantitative palynological analysis of 54 samples of cold water coral carbonate mounds in the Moroccan margin of the Western Mediterranean Sea (Alboran Sea), provide a more complete knowledge of the history of the palaeoenvironment and climate throughout the Upper Pleistocene–Upper Holocene research period (14.02–3.47 kyrs BP). The organic remains revealed a dominance of dinoflagellate cysts over the continental fraction, which despite their low representativeness is proving to be a valuable tool for the palaeoclimate interpretation.

Our first results point to (1) an inner neritic depositional environment with warm microflora (pollen) during the Bölling/Alleröd, indicating a warm-humid climate; (2) and a pronounced cooling marked by cold microfauna (dinoflagellate cysts) and microflora (pollen) indicating a cold-dry climate, with an outer neritic to oceanic environment during the Younger Dryas; (3) following this comes the Holocene, which is distinguished by the exceptional development of warm taxa and a climatic cyclicity between warm-dry, warm-arid, warm-semi-arid and warm dry climates, with an environment that varies from inner-outer neritic to inner-oceanic, with a noteworthy optimum of warm microfauna, such as the two species *Spiniferites mirabilis* and *Impagidinium aculeatum*.

These climatic and palaeoenvironmental conditions described by dinoflagellate cysts and pollen have therefore contributed to a better understanding of the development of cold-water corals in the studied area.

Conjoined tests in epiphytic populations of *Sorites*: Insights into the occurrence of tests with multiple proloculi in fusulinids

Susan Richardson[1]

[1]Wilkes Honors College, Florida Atlantic University, Jupiter (FL), USA

✉ srichardson@aya.yale.edu

Conjoined tests occur at frequencies ranging from 1.2–2.5 % in epiphytic populations of *Sorites* that live attached the seagrass *Thalassia testudinum* growing in shallow coastal habitats of Florida and Panama. Conjoined tests develop when asexually produced progeny are released from the brood chambers of the parental test, and disperse and settle within close proximity to genetically identical siblings. Juvenile tests develop normally until their tests abut after which they coalesce and form common chambers around both tests. Conjoined tests continue to grow as one unit and may eventually

produce brood chambers and a 'clutch' of offspring with megalospheric proloculi. Repeated episodes of asexual reproduction in the life cycle of *Sorites* facilitates vertical transmission of the endosymbiotic dinoflagellates; however, only a small subset of the endosymbiont population is transmitted to each propagule during multiple fission resulting in population bottlenecks and reduced genetic variation in the progeny's endosymbiont populations. Occasional fusion between clonally produced tests, therefore, may serve to increase the genetic diversity of algal endosymbiont populations. The insights gained from ecological studies of modern symbiont-bearing *Sorites* populations are used to reinterpret the occurrence of tests with multiple proloculi in fusulinids and infer the taxonomic distribution of algal endosymbiosis within the clade.

Nutrient availability mediated response of eutrophic lake to climatic change at Late-Glacial/Holocene transition—diatom record from Central Europe

Anna Tichá[1], Tomáš Bešta[2], Daniel Vondrák[3], Petra Houfková[4], and Vlasta Jankovská[2]

[1]Department of Botany, Univerzita Karlova, Prague, Czech Republic; [2]Department of Aquatic Microbial Ecology, Biologické Centrum AV ČR, v. v. i., Ceská Budejovice, Czech Republic; [3]Institute for Environmental Studies, Univerzita Karlova, Prague, Czech Republic; [4]Laboratory of Archaeobotany and Palaeoecology, Jihočeská univerzita v Českých Budějovicích, Ceské Budejovice, Czech Republic

✉ anna.postulkova@natur.cuni.cz

Shallow lowland lakes naturally tend to eutrophy and can remain in a stable state for a long time until crossing a critical nutrient threshold. How were these unique freshwater ecosystems challenged by abrupt climatic changes connected with the Late-Glacial/Holocene (LG/H) transition? Here, we present a diatom record from a large shallow lake (former Komorany Lake,

50.53° N, 13.53° E, surface area ~25 km^2). Sediment cores obtained in the 1980s by rescue sampling were subsampled and four bulk samples were selected for accelerator mass spectrometry radiocarbon dating. Supported by results of other analyses (chironomids, pollen, X-ray fluorescence, and loss on ignition), the diatom record suggested a quite stable character of the lacustrine ecosystem with high nutrient availability along the LG/H transition. Interestingly, the proportion of nutrient-demanding taxa decreased towards the Holocene simultaneously with the rise of terrestrial and aquatic primary productivity in the Komorany Lake record. While the limitation of biomass production by harsh conditions during the Late Glacial possibly allowed a higher availability of nutrients for surviving organisms, later higher nutrient turnover during enhanced primary production in the Holocene probably reduced instantaneous concentrations of nutrients. During the LG/H transition, the eutrophic lakes likely represented very stable ecosystems despite drastic changes in the surrounding landscape. We communicated our conclusions in detail in Tichá et al. (2019).

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