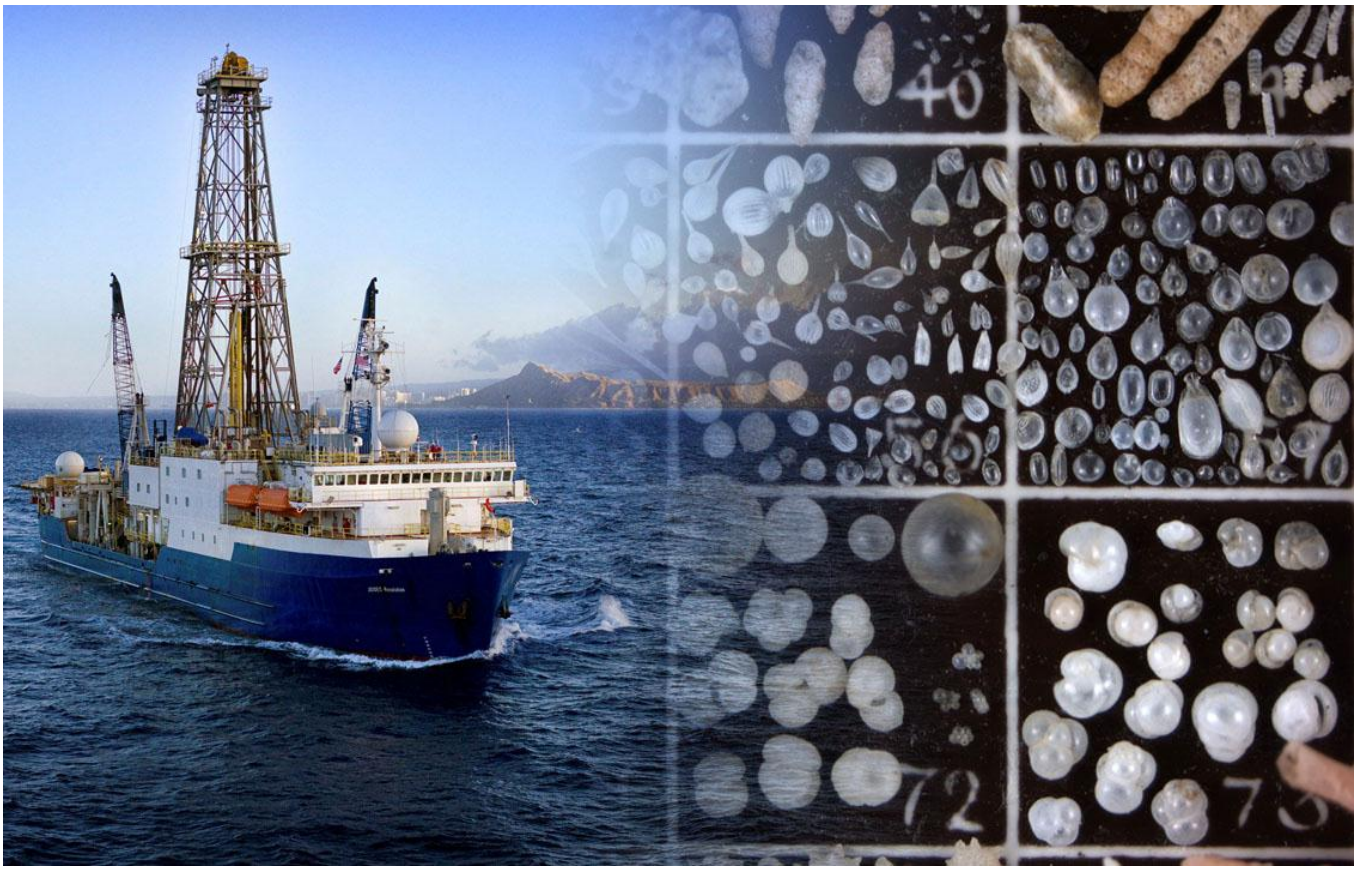
The Micropalaeontological Society

http://www.tmsoc.org

Micropalaeontology and the IODP:

Past, Present and Future Applications



18th & 19th November 2013

The Natural History Museum, London

twitter

@MicropalaeoSoc #TMSoc2013 @NHM_Micropalaeo

Wireless access
NHM-Treasures

The Micropalaeontological Society would like to thank the following organisations for their generous sponsorship and support:

WELCOME

On behalf of The Micropalaeontological Society, we would like to welcome you to The Natural History Museum for the 2013 conference. We are following in the footsteps the extremely successful conference held last year at the British Geological Survey in Keyworth, where for the first time, the event was spread over two days. The resounding success of that meeting lead us to keep the same format this year, and it seems to have been well-received since we are delighted to welcome almost 150 delegates to the conference. This includes scientists from across the world, including registrants from America, Canada, France, Germany, the Netherlands, New Zealand, Switzerland and Tunisia, to name a few.

The theme of the conference is 'Micropalaeontology and the IODP; Past, Present and Future Applications'. The theme coincides nicely with the transition from the Integrated Ocean Drilling Program to the new International Ocean Discovery Program and publication of the 10yr Science Plan '*Illuminating Earth's Past, Present and Future*'. Commensurate with the renewal of the international programme, the domestic NERC-funded UK-IODP programme has been successfully renewed and will run through to September, 2018, when it will be subject to review. The conference is however more timely given the fact that the National Science Foundation has yet to commit to renewing the IODP funding beyond the current one year extension. The extremely strong conference turnout, combined with the high quality and quantity of both oral and poster presentations scheduled over the next two days, is testimony to the invaluable contribution the IODP provides to earth system science and, indeed, to society as a whole.

We have a strong thematic session scheduled for the first day of the conference, with Xavier Crosta, Anne de Vernal, Tom Dunkley Jones, Heiko Pälike and Bridget Wade presenting invited keynote talks on diverse aspects of micropalaeontology and the IODP. This will be followed by the TMS AGM, a drinks reception and then the conference meal. The second day is dedicated to open oral presentations covering all areas of micropalaeontology. Poster sessions will also run throughout the conference. As you can see from the abstract book we have 16 talks in the open session and over 40 posters. This is an impressive celebration of micropalaeontology and a good indication of the health of the discipline.

Finally, we are pleased to announce that next year's conference will take place at the Oxford University Museum of Natural History, so please keep an eye out for further information regarding this in the coming months.

We hope you enjoy the conference, many thanks for contributing to it.

Tom Hill, Steve Stukins & Giles Miller
(NHM Convenors)

Tom Hill (NHM), Jeremy Young (UCL) and Bill Austin (St Andrews)
(TMSoc Scientific Committee)

A MESSAGE FROM THE UK-IODP

Scientific ocean drilling is arguably one of the most successful international programmes in science. This owes both to the magnitude of the questions which may be answered through sampling of the sediments and rocks below the ocean floor, but also to the long-term running of the programme itself (DSDP:1968-1983, ODP:1983-2003, IODP:2003-present). This longevity allows for sustained research effort to tackle large-scale problems across the Earth Sciences. The programme is intrinsically cross-disciplinary and collaborative, attracts world class researchers, and provides an ideal platform for training which is valued in both academia and industry. As one industry representative stated during the review of IODP in the UK a couple years ago: wrote "To even think that the UK would consider stepping out of support for the IODP is, quite frankly, bizarre"

While IODP-related research has progressed many fields of research, it has perhaps been fundamental to the development of others, notably Palaeoceanography. UK-IODP are very happy to support this conference as Micropalaeontology is crucial to many aspects of IODP research and the UK scientific community is exceptionally strong within the field.

Dayton Dove
UK-IODP Science Programme Coordinator
British Geological Survey
(ukiodp@bgs.ac.uk)
http://www.bgs.ac.uk/iodp/

Micropalaeontology and the IODP: Past, Present and Future Applications

Monday 18th and Tuesday 19th November 2013
at the Natural History Museum

Annual Conference of The Micropalaeontological Society, 2013

Monday 18th November

10.30 – 13.00: Coffee and Conference Registration
Delegates will have the opportunity to take part in optional tours of the micropalaeontology unit and associated microfossil collections, led by Steve Stukins and Giles Miller.

13.00-16.10: Keynote Lectures on 'Micropalaeontology and the IODP'

13.00-13.10: Welcome and introduction, by Richard Herrington (Head of Earth Sciences, Department of Earth Sciences, NHM) and Andy Fleet (Assistant Director of Science, NHM)

13.10-13.40: *Integrated microplankton records of equatorial pacific ecosystem perturbations across the Eocene/Oligocene transition* by **Tom Dunkley Jones**, K. Prentice, T. Moore, J. Baldauf, P. Bown, K. Edgar, B. Wade and J. Lees

13.40-14.10: *Planktonic foraminifera and ocean drilling: past, present and future applications* by **Bridget Wade**

14.10-14.40: *Palynological insights into climate, ice and ocean conditions during "warm" intervals of the Late Cenozoic in NW North Atlantic* by **Anne de Vernal**, Bianca Fréchette and Claude Hillaire-Marcel

14.40-15.10: TEA/COFFEE

15.10-15.40: *Forcings (millennial to pluri-annual) of Holocene sea ice changes, Adélie Land, East Antarctica* by **Xavier Crosta**, L. Barbara, P. Campagne, D. Denis, R. Dunbar, C. Escutia, J. Etourneau, H Goosse, T. Gregory, G. Massé, R. Melis K., Mezgec, J. Pike, S. Schmidt and B. Stenni

15.40-16.10: *The Integrated Ocean Discovery Program – Quo Vadis Micropalaeontology?* by **Heiko Palike**

16.10-17.30: SOCIETY BUSINESS Annual General Meeting of The Micropalaeontological Society, including the awarding of various prizes

17.30-19.00: POSTER SESSION and drinks reception in the Flett Theatre Foyer
The drinks reception has been kindly sponsored by Petrostrat

19.00: Depart the NHM for conference dinner at Med Kitchen, Gloucester Road, SW7 4PL.
The conference dinner has been kindly sponsored by Neftex

Tuesday 19th November

08.00-09.00 TEA/COFFEE

09.00-15.00: Open talks on Micropalaeontology:

09.00-09.15: *Micropaleontology in the new International Ocean Discovery Program*
Denise K. Kulhanek

09.15-09.30: *Radiolarian biostratigraphy and Neogene to Recent palaeoceanographic evolution of the Middle American Trench area off Costa Rica*
Maria I. Sandoval, P.O. Baumgartner Peter and Scientific Party of IODP (Integrated Ocean Drilling Program 344 Expedition)

09.30-09.45: *Preservation of fossil fish tooth Nd isotope signals under varying redox conditions*
Claire E. Huck, T. van de Flierdt, S.M. Bohaty, F.J. Jimenez-Espejo, S. Hammond and IODP Expedition 318 Scientists

09.45-10.00: *Preservation and Reliability of geochemical Proxy Data from Foraminifera*
Janett Voigt, E. Hathorne and M. Frank

10.00-10.15: *Nannotax3 and Web delivery of Taxonomy*
Jeremy R. Young, J.A. Lees and P. R. Bown

10.15-10.30: *Neogene Dinoflagellates and Global Change*
Jamie L. Boyd, A.M. Haywood, J.B. Riding, M.J. Pound and V.C. Bowman

10.30-11.30: POSTER SESSION *Sponsored by AASP – The Palynological Society*

11.30-11.45: *Understanding diversity gradients in planktonic foraminifera*
Isabel S. Fenton, P.N. Pearson, T. Dunkley-Jones and A. Purvis

11.45-12.00: *Can "fossil speciation" predict molecular evolution?*
Thomas H.G. Ezard, G.H. Thomas and A. Purvis

12.00-12.15: *Forcing factors on Caspian Sea level changes in the Late Pleistocene and Early Holocene: contribution of palynology*
Suzanne A.G. Leroy, A. Kakroodi, F. Chalié, A. Tudryn, S. Kroonenberg, H. Lahijani and K. Arpe

12.15-12.30: *A high-resolution sub-Antarctic record of mid- to late Holocene climate and vegetation changes at Fan Lake, South Georgia*
Stephanie Strother, U. Salzmann, S.J. Roberts, D.A. Hodgson, J. Woodward, W. Nieuwenhuyze, M. Sterken, E. Verleyen, W. Vyverman, S. Moreton

12.30-13.30: LUNCH

13.30-13.45: *A hotspot of modern foraminiferal diversity: The Raja Ampat archipelago (New Guinea)*
Meena Förderer and M. R. Langer

13.45-14.00: *Late Quaternary dynamics of the Congo (Zaire) River plume: element ratios and planktonic foraminiferal evidence.*
Els Ufkes, C. Straathof and J. Stuut

14.00-14.15: Elucidation of cryptic palaeoenvironmental cycles using unconventional microfossils.
G. Wyn Hughes

14.15-14.30: *Community assembly, biodiversity and neutral modelling of dinoflagellates from the early Eocene of the Rockall Shelf: Rich but random.*

Guy J. Harrington, M.O. Cuthbert and S.M. Jones

14.30-14.45: *Experiments with the propagules of deep water benthic foraminifera*
Chris J.Duffield and E. Alve

14.45-15.00: *Controls on the uptake of Mg, Sr and Li into the calcite of benthic foraminifera* Uvigerina peregrina
William R. Gray, M. Wolthers and J.A. Holmes

15.00: END OF CONFERENCE

CONFERENCE DINNER

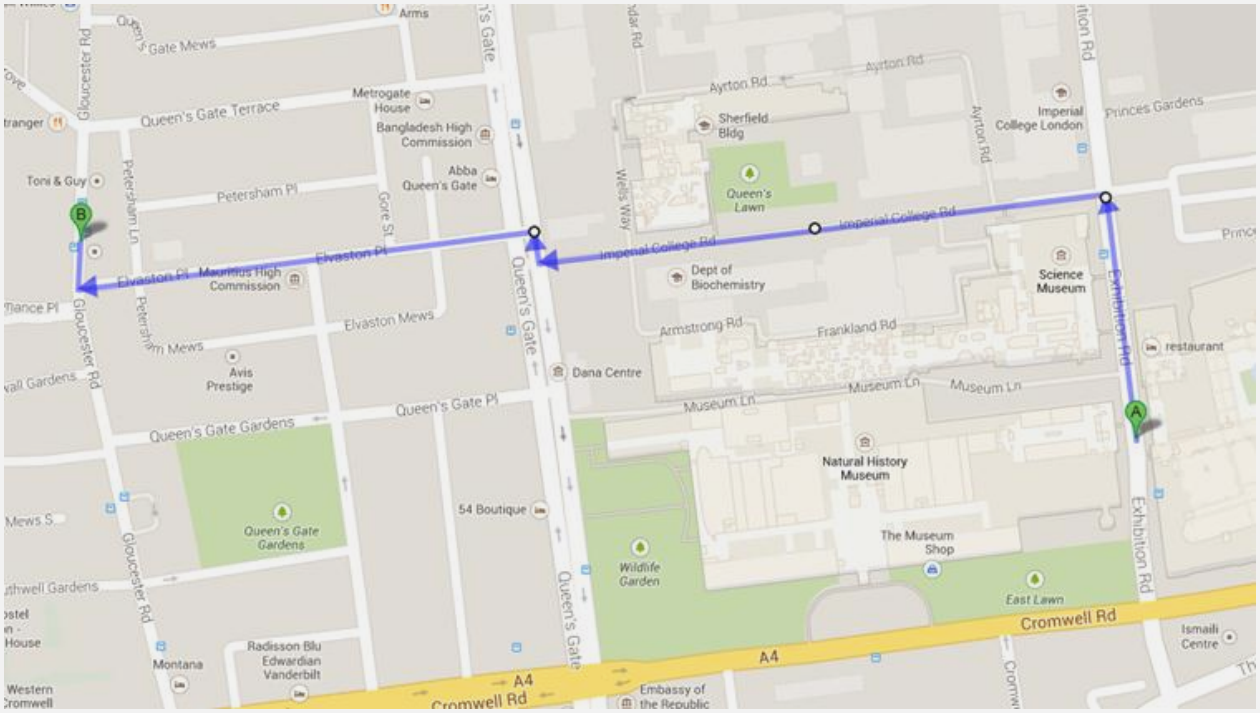
MONDAY 18TH November, c. 7.30pm

The venue for the conference dinner is **Med Kitchen**, located a c. 5-10minute walk from the Natural History Museum, at 25–35 Gloucester Road, SW7 4PL

We will then make our way on foot to the restaurant once the drinks reception has finished, in the hope for the meal to commence at around 7.30pm.

A basic map to assist delegates in getting to the restaurant is provided below. If you have any concerns, please find one of the conference organisers for assistance.

Exit the Natural History Museum from the Flett Theatre entrance and head north up Exhibition Road. Turn left (west) and walk to the end of Imperial College Road. Cross over Queen's Gate and walk west along Elvaston Place. Med Kitchen is located on the corner of Elvaston Place and Gloucester Road



Forcings (millennial to pluri-annual) of Holocene sea ice changes, Adélie Land, East Antarctica

X. Crosta[1*], L. Barbara[1], P. Campagne[1], D. Denis[1], R. Dunbar[2], C. Escutia[3], J. Etourneau[4], H Goosse[5], T. Gregory[6], G. Massé[4], R. Melis[7] K., Mezgec[7], J. Pike[6], S. Schmidt[1], B. Stenni[7]

[1] EPOC, UMR-CNRS 5805, Université Bordeaux 1, Talence, France
[2] Stanford University, Stanford, USA
[3] Instituto Andaluz de Ciencias de la Tierra, CSIC-Univ. De Granada, Granada, Spain
[4] LOCEAN, UMR-CNRS/UPCM/IRD/MNHN 7159, UPMC, Paris, France
[5] Earth and Life Institute, Université Catholique de Louvain, Louvain-la-Neuve, Belgium
[6] School of Earth and Ocean Sciences, Cardiff University, UK
[7] Department of Geosciences, University of Trieste, Italy
*corresponding author: x.crosta@epoc.u-bordeaux1.fr

Thick sediment sequences preserved on the Antarctic coastal shelf allow for high resolution investigation of the natural Holocene ocean and climate changes on which the recent warming took place.

I will here review high resolution investigations of sea ice dynamics based on micropalaeontological and biomarker data in several cores from the coastal East Antarctic area (Images core MD03-2601 for the Holocene period; IOPD site U1357B for the last 2000 years and interface core CB2010 for the last 300 years). These records identify different forcing of the seasonal sea ice at different timescales.

Sea ice conditions off East Antarctica (Dumont D'Urville Trough) were lesser during the mid-Holocene than during the Late Holocene. This long-term Holocene climatic evolution of East Antarctica is explained by a combination of a delayed response to local seasonal insolation changes coupled with the long memory of the Southern Ocean. Rapid variations in sea ice conditions are superimposed onto the Holocene trend. These centennial oscillations appear controlled by solar activity and internal climate variability (Southern Ocean thermohaline anomalies).
Sea ice conditions off East Antarctica over the last 2000 years (Dumont D'Urville Trough) appear out-of-phase with known climatic periods in the Northern Hemisphere and with climate over Antarctica. Diatoms and biomarkers demonstrate warmer and less icy conditions during the 200-800 AD period, colder and icier conditions during the 800-1600 AD period and again warmer and less icy conditions during the 1600-1850 AD period. Cyclicities of ~120 and ~400 years appear the most significant oscillations, calling again on solar variability and internal climate variability as the main drivers at these timescales. However, investigation of thin sections on cores MD03-2601 and IODP U1357B indicate that sub-decadal cyclicities were also present in the diatom record assemblages during both the Mid-Holocene warm period and the Late Holocene cold period, suggesting a control of inter-annual sea ice waning and waxing by climate modes such as the Southern Annular Mode and the ENSO.
Sea ice conditions in Mertz Region primarily respond to the Mertz Tongue internal dynamic. A large polynya forms west of the Mertz Tongue when the latter protrudes into the ocean while fast sea ice covers the area after a Mertz Tongue calving. Diatom and biomarker records in core CB2010 (Commonwealth Bay) show a cyclicity of ~80 years and extend back our knowledge of the Mertz Tongue dynamic over the last 300 years.

Keywords: Antarctica; Holocene; Sea ice; diatom; forcings

KEYNOTE ABSTRACTS

Integrated microplankton records of equatorial Pacific ecosystem perturbations across the Eocene/Oligocene transition

Tom Dunkley Jones[1*], Katy Prentice[2], Ted Moore[3], Jack Baldauf[4], Paul Bown[5], Kirsty Edgar[6] Bridget Wade[5] and Jackie Lees[5].

[1]School of Geography, Earth and Environmental Sciences, University of Birmingham
t.dunkleyjones@bham.ac.uk
[2]Department of Earth Science and Engineering, Imperial College London, London, SW7 2AZ, UK
[3]Department of Earth and Environmental Sciences, University of Michigan
[4]Department of Oceanography, Texas A&M University
[5]Department of Earth Sciences, University College London
[6]School of Earth and Ocean Sciences, Cardiff University
*corresponding author: t.dunkleyjones@bham.ac.uk

The Eocene-Oligocene transition (E/OT) witnessed the most significant climatic change in the Cenozoic with a fundamental reordering of the planet's oceanic and atmospheric circulation, the cooling of deep and high-latitude waters and the formation of continental scale ice sheets on Antarctica. Records from the equatorial Pacific show rapid and highly correlated increases in deep-ocean oxygen and carbon isotopes and a drop in the Calcium Carbonate Compensation Depth (CCD) of over a kilometre (Coxall *et al*. 2005). The role of surface ocean productivity changes, especially at low latitudes, within this carbon cycle perturbation remains open to question, as are the immediate causes of significant extinction events in both the coccolithophore algae and planktic foraminifera through the E/OT (Pearson *et al.* 2008).

Here we present new, detailed and integrated micropalaeontological and geochemical analyses of radiolaria, diatoms, planktic foraminifera and coccolithophores from IODP Site U1334 in the eastern Equatorial Pacific. These clearly show a series of significant biotic events, including enhanced extinction in the radiolaria and the loss of the multi-rayed discoasters, prior to the onset of the major phases of Antarctic glaciation. The timing and nature of these changes supports progressive cooling in the latest Eocene, associated with enhanced upwelling in the equatorial Pacific, prior to the major phase of Antarctic ice-sheet growth. Rapid expansion of continental ice-sheets is likely a threshold response to this gradual cooling trend but in turn had a significant impact on nutrient cycling between the Southern Ocean and zones of tropical upwelling.

REFERENCES

Coxall, H. K., Wilson, P. A., Palike, H., Lear, C. H. & Backman, J. 2005. Rapid stepwise onset of Antarctic glaciation and deeper calcite compensation in the Pacific Ocean. *Nature* 433: 53-57.

Pearson, P.N, McMillan, I. K., Wade, B. S., Dunkley Jones, T., Coxall, H. K., Bown, P. R. & Lear, C. H. 2008. Extinction and environmental change across the Eocene-Oligocene boundary in Tanzania. *Geology* 36: 179-182.

The Integrated Ocean Discovery Program – Quo Vadis Micropalaeontology?

H. Pälike[1]*

[1]Center for Marine Environmental Sciences (MARUM), University of Bremen, 28359, Bremen, Germany
*corresponding author: hpaelike@marum.de

The Integrated Ocean Drilling Program and its successors have benefited hugely from Micropalaeontological research, and at the same time provided many new samples and spawned new studies not only advancing biostratigraphy but also research into species evolution and distribution changes with time. In this contribution I will review some of the recent advances, and provide an update of the current status of the *Joides Resolution* Facility. The new IODP has been re-organised into three more distinctly operated facilities, bringing new challenges and opportunities. How can micropalaeontologists benefit and contribute to this new world? How can we exploit the legacy of the existing cores and samples?

Keywords: Integrated Ocean Discovery Program; IODP; Joides Resolution; Taxonomy

Palynological insights into climate, ice and ocean conditions during "warm" intervals of the Late Cenozoic in NW North Atlantic

Anne de Vernal[1], Bianca Fréchette[1] and Claude Hillaire-Marcel[1]

[1]Geotop, Université du Québec à Montréal, Canada
*corresponding author: devernal.anne@uqam.ca

The analysis of organic walled microfossils from marine sediments permits to document simultaneously the vegetation of adjacent lands using pollen and spores spectra, as well as surface ocean conditions, based on dinocyst assemblages. Palynology thus yields exclusive information for land-sea correlation adding to i) quantitative reconstructions of past ocean and climate parameters from transfer functions and ii) information on terrigenous sediment sources from reworked palynomorphs. Noteworthy are dinocyst assemblages that record relatively high species diversity along continental margins in estuarine to open ocean settings from low latitude to Arctic seas. They revealed highly achieving proxies for reconstructing seasonal sea-surface temperature and salinity, as well as the sea-ice cover and overall productivity during the late Cenozoic.

Examples of palynological records from ODP (646) and IODP (1302/1303, 1305) sites in the Labrador Sea illustrate such multi-fold reconstructions. They have been used to make inferences about land and ocean conditions during warm interglacial of the Quaternary and the Pliocene. Data indicate that each interglacial of the last Ma was unique. For example, the marine isotope stage MIS-5e (128-117 ka) data show that optimal conditions, about to 5°C warmer than today were reached, and that a fern-dominated vegetation developed over southern Greenland, then characterized by a mild climate despite the persistence of a still voluminous ice sheet. Complementary isotopic and geochemical information also suggest strong stratification in surface water, thus conditions unfavorable for vertical convection and intermediate-deep water formations. As another example, the data of marine MIS-11 (424-374 ka) show similar to modern ocean conditions, but spruce forest development on the Greenland, which was likely deglaciated, possibly due to the long duration the interglacial.

For what concern the Pliocene, quantitative reconstructions of ocean parameters from dinocysts are equivocal because of the occurrence of extinct taxa with uncertain ecological affinities. Nevertheless, changes in taxa occurrences and concentrations indicate variations in productivity and sea-surface conditions, but the dominance of cool temperate taxa suggests temperature not unlike those observed today in southern Labrador Sea and northern North Atlantic. The Pliocene assemblages also yielded abundant prasinophytes and acritarchs that reflect nutrient rich and low salinity surface waters. At ODP Site 646, Pliocene sediments contain abundant pollen of coniferous trees and spores of Sphagnum, which indicate inputs related from a boreal-type forest then occupying southern Greenland, thus a cool temperate climate. The overall palynological data of ODP Site 646 suggest major transitions at about 4, 2.4 and 1.2 Ma with dinocyst taxa extinctions. The 2.4 Ma transition seems also to be marked by a drastic decrease of pollen input which might reflect significant ice growth on Greenland. Over the last million years, the only interval that shows similarities with >2.4 Ma conditions with coniferous woodland development on Greenland was MIS 11. Hence, dense boreal vegetation on Greenland seems to have characterized the Pliocene prior to 2.4 Ma and some subsequent episodic intervals, but sea surface conditions were not necessarily warmer in the Labrador Sea than they have been during the present interglacial.

Planktonic foraminifera and ocean drilling: past, present and future applications

Bridget Wade[1*]

[1]Department of Earth Sciences, University College London, Gower Street, London, WC1E 6B,UK.
*corresponding author: b.wade@ucl.ac.uk

The study of ancient ecosystems and their response to climatic change is a principal topic within palaeontology. IODP and its predecessors have had a major contribution to the understanding of planktonic foraminifera evolutionary history through the recovery of expanded sedimentary successions, rich in microfossils. Planktonic foraminifera are extensively utilized in Cenozoic marine biostratigraphy. Dating of biostratigraphic events has been based largely on correlations to the magnetostratigraphy in deep sea cores of the Deep Sea Drilling Project and Ocean Drilling Program, as well as outcrop sections. New stratigraphic reference sections drilled by IODP provide the opportunity to re-evaluate Cenozoic bioevents at much higher resolution than previously attempted as well as linking foraminiferal records to nannofossil, stable isotope, astronomical and palaeomagnetic records for global correlation. Here I present recent developments, progress and future directions in Cenozoic planktonic foraminiferal biochronology.

Neogene Dinoflagellates and Global Change

J.L. Boyd[1]*, A.M. Haywood[1], J.B. Riding[2], M.J. Pound[3] and V.C. Bowman[4]

[1]School of Earth and Environment, University of Leeds, Leeds,LS2 9JT, UK;
[2]British Geological Survey, Kingsley Dunham Centre, Nottingham, NG12 5GG, UK;
[3]Department of Geography, Northumbria University, Newcastle, NE1 8ST, UK;
[4]British Antarctic Survey, Cambridge, CB3 0ET, UK.
*corresponding author: ee08jll@leeds.ac.uk

The Neogene Period (23.03 to 2.59 Ma) has been described as the making of the modern world (Potter and Szatmari, 2009) because of the changes that occurred creating modern conditions. The Neogene had significantly warmer climates than today and witnessed dramatic climate transitions, and having a better understanding of these changes is beneficial to understanding possible future climate change. Proxies have been established as an essential tool in enhancing our understanding of climate change and ocean circulation of the past and dinoflagellate cysts are one such proxy that has so far been underrepresented in the Neogene. Dinoflagellate cysts make excellent proxies because their cysts preserve well and temperature, salinity, ice cover and nutrient content limit their abundance and diversity. In order to understand the evolution and development of the oceans through the Neogene and to develop dinoflagellate cysts as a proxy for the Neogene, relevant information on Neogene dinoflagellates has been collected and collated from 230 published studies. Over 400 globally distributed sites, containing a total of 1616 discrete layers have been entered and made internally consistent into the Tertiary Oceanic Parameters Information System database (TOPIS). The database contains location, age, dating method and a list of taxa found for each site. It also contains the sediment and ocean setting in order to determine what environmental factors affect the assemblage diversity and distribution in the Neogene. The data has been grouped using cluster analysis (PRIMER 6) into 33 groups. The clusters are found globally and represent assemblages that prefer certain living conditions. Several clusters show preferences to living at certain latitudes, specifically between 30 to 60°N in the North Atlantic or around Europe. Other clusters are grouped by the species amongst the discrete layers preferring certain ocean environments such as brackish waters or inner neritic conditions helping to define Neogene dinoflagellate biogeography. The clusters often contain discrete layers with a narrow time band suggesting that the dinoflagellate assemblages change rapidly with time. The cluster results are encouraging and support the use of dinoflagellate cyst as a Neogene climate proxy and have begun to give information of rapidly switching climates and conditions throughout the Neogene.

Keywords: Neogene; dinoflagellate cysts; cluster analysis; climate change.

REFERENCES

Potter, P.E., Szatmari, P. (2009) Global Miocene tectonics and the modern world. Earth-Science Reviews, 96, 279-295.

Experiments with the propagules of deep water benthic foraminifera

Christopher James Duffield[1]*, Elisabeth Alve[1]

[1]Department of Geosciences, University Of Oslo, Norway
*corresponding author: c.j.duffield@geo.uio.no

An accurate interpretation of the palaeoecology of fossil taxa requires knowledge of the ecology of their modern counterpart. The propagule method, a novel and easily carried out experiment, provides a means to investigate and provide further information on the ecology of benthic foraminifera (Goldstein & Alve, 2011; Alve & Goldstein, in press).

A number of experiments have been carried out and are underway using the propagules of deep water benthic foraminifera from the Oslofjord, Norway. Before starting an experiment, sediment is washed with sea water on a sieve to separate propagules from larger organisms. The fine sediment fraction containing the "propagule bank" is then used to create microcosms which are kept in the dark and at a temperature which simulates natural conditions. At the end of the experiment the sediment from the microcosms is washed once more, this time on a sieve with larger apertures than the sieve that was initially used. Therefore any foraminifera retained on the sieve have grown during the course of the experiment. For an individual to have grown the experimental conditions must have been favourable, or at least tolerable.

The propagule method is versatile and can be used to investigate a wide range of different environmental parameters. Here investigations have primarily focused on the response to different types of food (or lack of) and changes relating to sediment depth, including oxygen.

Certain species (e.g., *Nonionella iridea, Stainforthia fusiformis* and *Textularia earlandi*) have been shown to require no input of food over an eight week long experiment in order to grow, a sufficient food source presumably already existing within the sediment. Other species (e.g., *Epistominella vitrea*) show a complete dependence on an input of an algal food source. Results show that preferences to certain foods may exist and that some algae (e.g. *Emiliania huxleyi*) can have a deleterious effect on benthic foraminifera.

The results from these experiments provide insight into the ecology of the modern benthic foraminifera and in doing so aid our interpretation and understanding of the conditions of the past.

Keywords: benthic foraminifera; propagule method; feeding experiment; ecology

REFERENCES

Alve E. and Goldstein, S.G., accepted, The Propagule Method as an experimental tool in foraminiferal ecology. In: Bernhard J.M. and Kitazato H. (eds.) *Experimental Approaches in Foraminifera: Collection, Maintenance and Experiments*. Springer

Goldstein, S. T. and Alve, E., 2011, Experimental assembly of foraminiferal communities from coastal propagule banks: *Marine Ecology Progress Series*, v. 437, p. 1- 11.

Can “fossil speciation” predict molecular evolution?

T.H.G. Ezard[1]*, G.H. Thomas[2] & A. Purvis[3]

[1]Centre for Biological Sciences, University of Southampton, Southampton, UK;
[2]Department of Animal and Plant Sciences, University of Sheffield, Sheffield, UK;
[3]Department of Life Sciences, Imperial College London; London; UK.
*corresponding author: t.ezard@soton.ac.uk

The IODP provides an abundant and astonishing resource for micropalaeontological approaches to studying the drivers of diversification, but what information does it hold about the biological processes underpinning molecular evolution? Here, we collate stratigraphic, phylogenetic and ecological data of Cenozoic macroperforate planktonic foraminifera to test whether differences in the rate of molecular evolution among species is explained by ecological factors (abundance, life history and environment) and by the numbers of speciation events according to fossil lineage, fossil morphospecies and molecular species concepts. The models will then be placed in the context of a controversial theory, which argues that speciation provokes a burst of rapid genetic change, giving molecular evolution a punctuational component. The controversy arises because, until now, these tests have been restricted to phylogenies that ignore extinct ancestors. The number of nodes between root and tips on the fossil lineage phylogeny was a statistically significant correlate of the rate of molecular evolution over the same root-to-tip path. The speciation counts from the fossil morphospecies and molecular species concepts, as well as the hypothesized ecological drivers had considerably less support. Our results showcase how the fossil record does contain signals of processes that drive genetic evolution, justifying calls to further marry fossil and molecular data when studying macroevolution over geological time-scales.

Keywords: comparative analysis; macroevolution; molecular evolution; planktonic foraminifera.

Understanding diversity gradients in planktonic foraminifera

I.S. Fenton[1,2]*, P.N. Pearson[3], T. Dunkley-Jones[4] and A. Purvis[1,2]

[1]Department of Life Sciences, Natural History Museum, Cromwell Road, London, UK
[2]Department of Life Sciences, Silwood Park Campus, Imperial College London, Ascot, Berkshire, UK
[3]School of Earth and Ocean Sciences, Cardiff University, Cardiff, UK
[4]School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham, UK
*corresponding author: isabel.fenton@nhm.ac.uk

The latitudinal diversity gradient (LDG) – whereby species-richness within a taxon is highest at low latitudes – is one of the most widespread patterns in macroecology, being found in almost all habitats, regions and clades whether terrestrial or marine. Many explanations have been put forward to explain the LDG, invoking different mixtures of present environmental conditions and Earth history as causal factors, but a general consensus is lacking (Hillebrand 2004).

The planktonic foraminifera provide an ideal group in which to study this phenomenon due to their global distribution, the abundance of their tests, our knowledge of their phylogeny and functional traits (Aze *et al*, 2011) and their excellent fossil record, which allows us to investigate this pattern in the past. Rutherford *et al* (1999) showed that the LDG in the Atlantic for Recent planktonic foraminifera is closely correlated with sea surface temperature. However, it is not clear whether sea surface temperature is itself the key variable, or whether the correlation arises because warmer seas tend to be more stratified and so have more niches available. Here, we test whether the structure of the water column or temperature itself has greater power to explain diversity patterns, looking across different oceans and incorporating phylogenetic and functional data as well as species numbers.

The Brown Foraminiferal Database (Prell *et al*, 1999) contains over 1200 records of abundance data for planktonic foraminifera across the world. Environmental data including the vertical temperature structure of the ocean at each site were obtained. Generalised Additive Models were run to test whether vertical temperature structure, temperature itself, or both are important in structuring Recent foraminiferal assemblages.

Results suggest a strong correlation between water column structure and planktonic foraminiferal diversity, although the strength of the correlation varies between the oceans. There is also initial evidence that the strength of the LDG in the past depended upon the strength of the latitudinal temperature gradient.

Keywords: Planktonic foraminifera; latitudinal diversity gradient; species richness; phylogenetic diversity; functional diversity

REFERENCES

Aze, T., Ezard, T.H.G., Purvis, A., Coxall, H.K., Stewart, D.R.M., Wade, B.S. & Pearson, P.N. (2011) A phylogeny of Cenozoic macroperforate planktonic foraminifera from fossil data. *Biological Reviews*, 86, 900-927

Hillebrand, H. (2004). On the generality of the latitudinal diversity gradient. *The American Naturalist*, 163 (2), 192-211

Prell, W., Martin, A., Cullen, J. & Trend, M. (1999) Brown University Foraminiferal Database. In, *IGBP PAGES/World Data Center-A for Paleoclimatology*

Rutherford, S., D'Hondt, S. & Prell, W. (1999) Environmental controls on the geographic distribution of zooplankton diversity. *Nature*, 400, 749-753

A hotspot of modern foraminiferal diversity: The Raja Ampat archipelago (New Guinea)

Meena Förderer[1]* & Martin R. Langer[1]

[1]Steinmann-Institute of Geology, Mineralogy and Paleontology, University of Bonn, Bonn, Germany
*corresponding author: m.foerderer@uni-bonn.de

The Raja Ampat archipelago, located in Indonesia's West Papua Province, is known for its tremendous coral reef biodiversity. Its remote location and difficult access conditions make this conglomerate of more than 1500 islands a largely unexplored area situated in the heart of the so-called Coral Triangle. Our study is the first analysis of a comprehensive set of sediment samples identifying the structure, composition and diversity of the benthic shallow-water foraminiferal fauna present in this region. The sample material covers a depth range between 1 to 50 meters and the full range of existing macrohabitats. All taxa were identified to species level and a new set of species was recorded. Scanning electron microscopy (SEM), stereo zoom microscopy and computed tomography (CT scan) were used for identification and illustration. We compared species diversity to other Indo-Pacific reefal sites to assess the significance of Raja Ampat as a hotspot for foraminiferal diversity and to shed new light on the processes generating species richness in the Coral Triangle. The results of our work exhibit an extraordinary high species richness of both smaller and larger benthic taxa in the foraminiferal assemblages. Our findings provide evidence that Raja Ampat is a unique hotspot of marine diversity and one of the world's biologically richest locations among reefs in modern oceans.

Keywords: Biodiversity; Foraminifera; Protists; Coral Triangle

Controls on the uptake of Mg, Sr and Li into the calcite of benthic foraminifera *Uvigerina peregrina*

W.R. Gray[1]*, M. Wolthers[2,3] and J.A. Holmes[1]

[1]Department of Geography, University College London, Gower Street, London, WC1E 6BT, UK
[2]Department of Chemistry, University College London, 20 Gordon Street, London WC1 H0AJ, UK
[3]Department of Earth Sciences-Geochemistry, Utrecht University, P.O Box 80021, 3508 TA Utrecht, the Netherlands
*corresponding author: william.gray.09@ucl.ac.uk

Trace element/Ca ratios in benthic foraminifera can potentially be used to elucidate past changes in bottom water temperature (BWT) and carbonate ion saturation (ΔCO_3^{2-}), providing the relationships between trace element uptake and environmental variables can be accurately constrained. Existing *Uvigerina peregrina* trace element/Ca calibrations are based on North Atlantic waters, super-saturated with respect to calcite. To constrain the effects of temperature and ΔCO_3^{2-} on trace element uptake and assess the fidelity of trace element-temperature/ΔCO_3^{2-} relationships in under-saturated ocean waters, we present new core-top *Uvigerina peregrina* trace element/Ca data from under-saturated waters in the North Pacific.

Core-top Uvigerina peregrina samples were obtained from the Bering Sea, Gulf of California, and Okhotsk Sea in the North Pacific Ocean. Sites include a wide range of bottom water temperatures (2 to 17 ^{o}C) and carbonate ion saturation states (-10 to 135 µmol kg^{-1}). Our results reveal a significant negative relationship between test size and Li/Ca in super-saturated waters, but not under-saturated waters. Mg/Ca, Sr/Ca, and Li/Ca ratios are significantly correlated to both BWT and ΔCO_3^{2-}, however the relationship between trace element/Ca ratios and BWT/ΔCO_3^{2-} differs in under-saturated and super-saturated waters. In under-saturated waters, Li uptake displays a higher sensitivity to ΔCO_3^{2-}, and Mg/Ca displays a weaker correlation to temperature/ΔCO_3^{2-}. The difference in trace element uptake in super-saturated and under-saturated waters may be related to either a change within the calcification process, or porewater chemistry in under-saturated waters. Our results indicate caution must be taken when interpreting trace element/Ca ratio records from sites where ΔCO_3^{2-} may have fluctuated above and below zero.

Keywords: *Uvigerina peregrina*; Mg/Ca; Li/Ca; Sr/Ca; North Pacific; carbonate ion saturation

Community assembly, biodiversity and neutral modelling of dinoflagellates from the early Eocene of the Rockall Shelf: Rich but random.

G.J. Harrington[1]*, M.O. Cuthbert [1,2] and S.M. Jones[1]

[1]Earth Sciences, GEES, University of Birmingham, Birmingham, B15 2TT, UK;
[2]Connected Waters Research Initiative Centre, The University of New South Wales, 110 King Street, Manly Vale, NSW 2093, Australia
*corresponding author: g.j.harrington@bham.ac.uk

A key component to understanding the maintenance of biodiversity is community assembly. This creates problems in the fossil record. The incompleteness of the record, and the vagaries of taphonomic processes, result in bias of representation and relative abundance patterns that are difficult to reconcile with living communities. We present the results of dinoflagellate cyst data (dinocysts) taken from 41 samples from a shallow well on the edge of the Rockall Trough (Ireland) that penetrates part of the early Eocene. This time interval represents the Cenozoic maximum of species richness for dinocysts and the greatest origination of morphotypes since the late Jurassic. During the Eocene the Rockall Trough subsided continuously leading to deposition of clastic sediments rich in dinoflagellates and terrestrial organic matter. The dynamic change in basin character forms the environmental driver of change in the time series represented by the sample set. The continental shelf becomes deeper and more distal and this is reflected in the sample composition of palynomorphs. Dinocysts are represented by 122 morphotypes and pollen and spores contain over 66 taxa. Samples indicate that with increasing distance apart from one another in the core, the composition is increasingly different. The driver of compositional change appears to be modification in co-occurrence patterns within-samples over time. We independently model the community using a simple stochastic neutral community model (NCM) devised by Sloan *et al*. (2007) explicitly designed to handle communities in which richness is incompletely measured, samples are small and the original relative abundance of taxa is unknown. It is a derivation of Hubbell's classic NCM in which random immigrations, births and deaths control the community through stochastic processes. Our results indicate that the Sloan *et al*. (2007) model can be fitted well to different moving time bins within the time series and indicates, furthermore, that immigration is very low into the community. Stochastic processes cannot be rejected as a causal mechanism based on the data modelled. Our results suggest that in the geological record, high dinocyst biodiversity is underpinned by stable communities in which successful immigration is a rare and random process.

Keywords: Eocene; dinoflagellate; neutral modelling; biodiversity; immigration.

REFERENCES

Sloan, W.T. *et al*. 2007. Modelling taxa abundance distributions in microbial communities using environmental sequence data. *Microbial Ecology* 53:443-455.

Preservation of fossil fish tooth Nd isotope signals under varying redox conditions

C.E. Huck*[1], T. van de Flierdt[1], S.M. Bohaty[2], F.J. Jimenez-Espejo[3], S. Hammond[4] and IODP Expedition 318 Scientists

[1]Imperial College, London, SW7 2AZ, UK;
[2]Ocean and Earth Science, National Oceanographic Centre, University of Southampton, Southampton, SO14 3ZH, UK;
[3]Institute of Biogeosciences (JAMSTEC), Yokosuka 237-0061, JAPAN;
[4]Open University, Walton Hall, Milton Keynes, MK7 6AA, UK
*corresponding author: c.huck10@imperial.ac.uk

Fossil fish teeth and debris are considered one of the most robust archives for reconstructing ancient seawater neodymium (Nd) isotope ratios and have been widely used to fingerprint individual water masses and their evolution through time. Little systematic work, however, has been done to verify the robustness of this proxy in marginal settings and under varying redox conditions.

During IODP Expedition 318, a shallow marine Eocene section was drilled offshore of the Wilkes Land margin, Antarctica. A lower Eocene section was recovered in Hole U1356A, spanning part of the warmest period of the Cenozoic - the Early Eocene Climatic Optimum (EECO). Striking cyclical variations between oxidised and reduced conditions are present within this drillcore interval. Since high-latitude climate conditions during the EECO are of particular interest for palaeoclimatic reconstructions, and Nd isotope reconstructions may provide insight into the early opening of the Tasmanian Gateway, we investigated the robustness of the early Eocene Nd isotope signal in fish debris at Site U1356.

Individual fish teeth were picked from the >125µm fraction of sieved samples and cleaned to remove detrital sediments. A subset of samples was reductively cleaned to remove Fe-Mn coatings. All samples were subjected to a standard two stage ion chromatography. Nd isotope ratios were determined on a Nu Plasma MC-ICP-MS at Imperial College. Main and trace element data, including rare earth element patterns, were obtained on an Agilent 7500a quadrupole ICP-MS at the Open University. Bulk sediment main and trace element data were obtained on an ICP-MS at the University of Granada.

Redox sensitive elements show evidence of oxic to dysoxic conditions within the sediment closely related to changes in the colour banding of core samples. However, neither the Nd isotopic composition, nor the REE patterns of the fish teeth show the same co-variation suggesting the fish teeth preserve their original seawater signal regardless of potential remobilisation of REEs during changing redox conditions within the sediments. Comparison between cleaned and uncleaned samples reveals identical Nd isotopic compositions and REE profiles, but decreased elemental concentrations in reductively cleaned samples. Fish tooth REE profiles show a typical distinct mid REE enrichment but have consistently positive Ce anomalies which do not track the expected changes in redox. This suggests that these features are linked more closely to the proximal site location of the samples rather than the redox state, with implications for potential incorporation of REE into fish teeth on shelf sites.

Elucidation of cryptic palaeoenvironmental cycles using unconventional microfossils.

G. Wyn Hughes[1,2,3]

[1]Applied Microfacies Limited, Tan Y Gaer, Llanbedr Dyffryn Clwyd, Rhuthun, Denbighshire LL15
[2]King Fahd University of Petroleum and Minerals, Dhahran. Saudi Arabia
[3]Department of Earth Sciences, The Natural History Museum, Cromwell Road, London, SW7 5BD, UK
*corresponding author: hughesmicropal@gmail.com

Palaeoenvironmental interpretation of Permian and Jurassic intertidal to very shallow marine peri-Tethyan carbonates, when examined in thin section is often challenging where typical shallow marine microfossils are either sparse or absent. A collection of microfossils originally considered as "microproblematica" because of their uncertain biological affinities are, however, often present. These include species of *Aeolisaccus, Gakhumella, Prethocoprolithus, Thaumatoporella, Favreina* and *Terebella*. These may or may not be accompanied by foraminifera, ostracods and other more conventional microfossils, owing to the extreme depositional environments of which hypersalinity is considered to be the prime adversity. Observations of their vertical distribution and relationship with carbonate fabrics reveal their environmental preferences that contribute to palaeoenvironmental interpretation within a spectrum of very shallow marine settings that previously precluded refinement. The recognition of high frequency depositional cycles and definition of cryptic reservoir layering in such shallow to marginal marine carbonates is now facilitated by the use of these microfossils from the Khuff, Hanifa, Jubaila, Arab and Hith formations of Saudi Arabia.

Keywords: Peri-Tethys; shallow marine; microproblematica; palaeoenvironment; Permian; Jurassic; carbonates

Micropaleontology in the new International Ocean Discovery Program

Denise K. Kulhanek[1]

[1]International Ocean Discovery Program, Texas A&M University, 1000 Discovery Drive, College Station, TX 77845, USA

*corresponding author: kulhanek@iodp.tamu.edu

As operator of the scientific drilling vessel JOIDES Resolution (JR), we at the United States Implementing Organization (USIO) strive for continual improvements to our shipboard laboratory systems and database. In the paleontology lab, these improvements include upgrading the microscopes available, as well as the addition of a scanning electron microscope (SEM). Earlier this year, the JR was outfitted with four Zeiss Discovery V8 stereomicroscopes with magnification capabilities up to 80× for observation of larger microfossils (e.g., foraminifera, ostracodes) and pieces of core for sedimentological and petrological analyses. Two of these microscopes also have a polarizing light base for transmitted-light applications. Later this year, we plan to replace three transmitted light microscopes with new Zeiss Axio Scopes that will have magnification changers (optivars) to allow for magnifications up to 2500×. The remaining Zeiss Axiophot microscope is equipped to offer differential interference contrast (DIC), phase-contrast illumination, and fluorescence. All light microscopes are outfitted with SPOT digital cameras. In May 2013, we installed and tested a Hitachi TM-3000 tabletop SEM and Leica EM ACE200 sputter coater for imaging microfossils and other lithological and petrological components. This instrument has since been used during two high-recovery paleoceanographic expeditions (Expedition 341 Southern Alaska Margin Tectonics, Climate & Sedimentation and Expedition 346 Asian Monsoon), receiving very positive feedback from the scientists who utilized it. Although the instrument can provide magnification up to 30,000×, using it on a moving ship limits the ability to obtain sharp focus at magnifications exceeding ~10,000×, with high-quality images captured at somewhat lower magnifications. During the upcoming months, we will also make some changes to the microscope lab configuration to maximize the available working space. Finally, we will deploy comprehensive taxonomic name lists (TNLs) later this year for several microfossil groups (planktonic foraminifera, calcareous nannofossils, radiolarians, and diatoms), developed by groups of experts who started with the lists currently available on the JR. These lists should help to standardize the taxonomy for data collected during expeditions and will also improve our ability to keep misspellings and other errors out of our database. The structure of the new TNLs provides flexibility for future database improvements, as well as the potential for linkages to external databases (e.g., Neptune). We plan to continue improving the micropaleontological capabilities for scientific ocean drilling during the new International Ocean Discovery Program (IODP) and look forward to hearing from the micropaleontological community regarding suggestions and feedback.

Keywords: IODP; micropaleontology; JOIDES Resolution

Forcing factors on Caspian Sea level changes in the Late Pleistocene and Early Holocene: contribution of palynology

S.A.G. Leroy [1]*, A. Kakroodi [2-3], F. Chalié[4], A. Tudryn[5], S. Kroonenberg[2], H. Lahijani[6] and K. Arpe [1-7]

[1]Institute for the Environment, Brunel University, Kingston Lane, Uxbridge UB8 3PH (London), UK.
[2]Department of Geotechnology, Delft University of Technology, The Netherlands.
[3]Department of Remote Sensing, Faculty of Geography, University of Tehran, Tehran, Iran.
[4]Aix-Marseille Université, CEREGE, UMR 7330 CNRS, UM34, Europôle de l'Arbois, BP80, 13545 Aix-en-Provence cedex 04, France.
[5]Laboratoire IDES UMR CNRS/UPSud 8148, Université Paris Sud, Bât. 504, 91405 Orsay cedex, France.
[6]Iranian National Institute for Oceanography (INIO), No. 3 Etamadzadeh St, Fatemi Avenue, Tehran 1411813389, Iran,
[7]Max Plank Institute for Meteorology, Hamburg, Germany.
*corresponding author: suzanne.leroy@brunel.ac.uk

Three Late Pleistocene and Holocene sequences from the south (a deep sea one and a coastal one) (Leroy *et al*., 2007, 2013 a and b) and the middle (a deep-sea one) (Leroy *et al*., in preparation) basins of the Caspian Sea (CS) have been studied for their palynological contents (pollen, dinocysts and non-pollen palynomorphs) in order to reconstruct past vegetation (hence climate) and past water salinities (hence water levels).

It has been established that the Younger Dryas is well marked by a regional aridification of the climate, but sea level remained high and was still part of the Khvalynian highstand.

The Mangyshlak lowstand in the Early Holocene is characterised by the most brackish (highest salinity) waters of the whole south basin deep sequence and a hiatus in the coastal one. No specific vegetation changes are observed. It is suggested that this water level lowering was due to a starvation of water inflow to the CS in response to hydrographic modifications of the main rivers - the Volga River and the Amu Darya - under a climate that has remained very dry at the beginning of the Holocene.

A delayed development of trees was indicated in the deep-sea cores and occurred not until 8.3 cal. ka BP, while in the coastal one that is located at the foot of the Elburz Mountains they survived the LGM being a refugium during glacial times.

During the Holocene the freshest waters are inferred between 8.3 and ≤4.0 cal. ka BP, linked to a connection of the CS with the Amu Darya, which was fed by the melting of glaciers on the Pamir Mountains. An overflow to the Black Sea is suggested. A sharp drop of water level is finally reconstructed at 3.9 cal. ka BP, before the start of the Neocaspian period.

In conclusion, at present the CS levels are mainly forced by the summer precipitation on the Volga drainage basin. In the past, the drainage basin of the Amu Darya (flowing from the Pamir Mountains) must be considered to understand the CS hydrological budgets. A lot of work remains however to be done in order to quantify better palaeo-salinities from the Caspian dinocysts because of the presence of endemic forms, species and even genera, only recently recognised (Marret *et al*., 2004).

Keywords: Younger Dryas; Holocene; Caspian Sea; water level; climate; vegetation; hydrology.

REFERENCES

Leroy S.A.G., Marret F., Gibert E., Chalié F., Reyss J-L. and Arpe K., 2007. River inflow and salinity changes in the Caspian Sea during the last 5500 years. *Quaternary Science Reviews* 26: 3359-3383.

Leroy, S.A.G., Kakroodi, A.A., Kroonenberg S.B., Lahijani H.A.K., Alimohammadian H., Nigarov A., 2013a. Holocene vegetation history and sea level changes in the SE corner of the Caspian Sea: relevance to SW Asia climate. *Quaternary Science Reviews* 70: 28-47.

Leroy S.A.G., Tudryn A., Chalié F., López-Merino L. and Gasse F., 2013b. From the Allerød to the mid-Holocene: palynological evidence from the south basin of the Caspian Sea. *Quaternary Science Reviews* 78, 77-97.

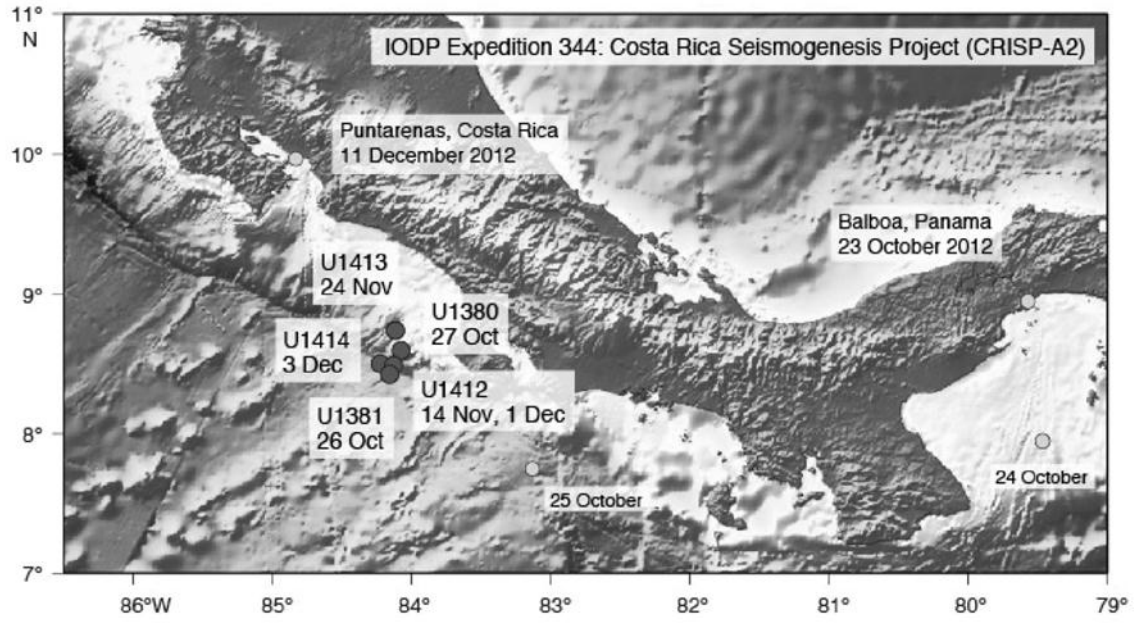
Marret F., Leroy S., Chalié F. and Gasse F. 2004. New organic-walled dinoflagellate cysts from recent sediments of central Asian seas. *Review of Palaeobotany and Palynology* 129: 1– 20.

Radiolarian biostratigraphy and Neogene to Recent palaeoceanographic evolution of the Middle American Trench area off Costa Rica

M.I. Sandoval[1]*, P.O. Baumgartner Peter1 & Scientific Party of IODP (Integrated Ocean Drilling Program 344 Expedition)[2]

[1] Institute of Earth Sciences & University of Lausanne, Switzerland;1015 Lausanne
*corresponding author: mariaisabel.sandovalgutierrez@unil.ch

The IODP Expedition 344 drilled a transect across the convergent margin off Costa Rica (Figures 1). Five sites were drilled during seven weeks of expedition: Site U1381 (8°25.7027'N, 84°9.4800'W, 2064.6 m water depth) is ~4.5 km seaward of the deformation front on the incoming (Cocos) plate, offshore Osa Peninsula. Recovery was 103.8 mbsf. Site U1414 (8°30.2304'N, 84°13.5298'W, 2459 m water depth), also located on the incoming plate, recovered 375.2 mbsf of sediments and basalt. The following sites were drilled in the Neogene slope apron of the upper (Caribbean) plate. Site U1380 (8°35.9879'N, 84°4.3918'W, 502.7 m water depth). The coring reached 800 mbsf. Site U1412 (8°29.1599'N, 84°7.7512'W, 1965 m water depth), involved drilling four holes with a maximum depth of 350.4 mbsf. Site U1413 (8°44.4593'N, 84°6.8095'W, 540 m water depth), recovered sediments to 582.2 mbsf.



Location of the drilled sites of IODP 344 Expedition off Costa Rica

Two sites from the Cocos plate were selected to obtain a detailed biostratigraphy of the middle Miocene to Recent oceanic sequence deposited on the incoming plate. At both localities radiolarian assemblages are well preserved and abundant. The sediments recovered from the two sites consist mainly of calcareous nannofossil ooze with foraminifers, diatoms and radiolarians. 295 samples were prepared with the standard method for Neogene Radiolarians.

The objectives of this study are: 1. detailed radiolarian biostratigraphy of the early-middle Miocene to Recent sequence of the incoming plate (Site U1381C, U1414A) and 2. a taxon-quantitative analysis aimed at tracing faunal changes related to the northward movement of the sites and to palaeoceanographic changes in context of the final closure of the Middle American Isthmus.

According to the modern plate motion vector, (7.3 cm/year; Mann, 2007). Site U1414 A and U1381 C were located slightly south of Equator during the middle Miocene. Radiolarian assemblages of that age should therefore reflect the influence of the cold tongue generated by the South Equatorial Current. In contrast, today the sites are located in the influence of the warm North Equatorial Countercurrent.

To achieve these objectives, 300 specimens will be counted per sample to obtain a representative faunal spectrum. An age model will be based on the radiolarian zonation for the tropics (Riedel *et al*, 1978), the nannofossil zonation and paleomagnetic data that will be analyzed by others scientists of the expedition.

Keywords: radiolarians; Cocos Plate; paleoceanography; Cenozoic, Miocene; IODP 344 Expedition; Costa Rica; Pacific ocean.

REFERENCES

Riedel, W.R., Sanfilippo, A., Westberg-Smith, M.J. 1978: Cenozoic Radiolaria. Stratigraphy and Evolution of Tropical Cenozoic Radiolarians *Micropaleontology*, Vol. 24, No. 1, pp. 61-96.

SanFilippo, A., Westberg-Smith, M. J. and Riedel, W. R., 1985: Cenozoic Radiolaria. In: Bolli, H. M., Saunders, J. B. and Perch-Nielsen, K., Eds., *Plankton stratigraphy*. Cambridge University Press, pp.631-712

Mann, P, Rogers, R & Gahagma, L . 2007: Overview of plate tectonic history and its unresolved tectonic problems. In: Jochen Bundschuh and Guillermo E . Alvarado., Eds. *Central America Geology, Resources and Hazards*, Taylor and Francis group, pp.201-238.

A high-resolution sub-Antarctic record of mid- to late Holocene climate and vegetation changes at Fan Lake, South Georgia

S. Strother[1]*, U. Salzmann[1], S.J. Roberts[2], D.A. Hodgson[2], J. Woodward[1], W. Nieuwenhuyze[3], M. Sterken[3], E. Verleyen[3], W. Vyverman[3], S. Moreton[4]

[1]Department of Geography, Faculty of Engineering and Environment, Northumbria University, Ellison Building, Newcastle upon Tyne, NE1 8ST, UK
[2]British Antarctic Survey, High Cross, Madingley Rd, Cambridge CB3 0ET, UK
[3]Laboratory of Protistology and Aquatic Ecology, Ghent University, B-9000 Gent, Belgium
[4]NERC Radiocarbon Facility, Rankine Avenue, East Kilbride, UK
*corresponding author: stephanie.strother@northumbria.ac.uk

Sub-Antarctic South Georgia is a key region for studying climate variability in the Southern Hemisphere, due to its positioning between the Antarctic Circumpolar Current and the Polar Frontal Zone. Here we present a 5.8 m high-resolution pollen record from Fan Lake on Annenkov Island, South Georgia, covering the last 7,000 years. Palynological and sedimentological analyses identify a warm late Holocene "climate optimum" from ca. 3800-2600 cal yr BP, which is followed by a rapid cooling starting at ca. 2600 cal yr BP. The Late Holocene cool and wet climate was interrupted by slightly warmer environmental conditions between 1750 - 700 cal yr BP that can be attributed to the Medieval Warm Period. Fluctuations in percentages of non-native long distance transported pollen grains from the South America (e.g. *Nothofagus, Podocarpus*) suggest highest transport by westerly winds occurred during the late Holocene cold periods between 2200 and 1600 cal yrs BP and after 700 cal yrs BP.

Keywords: Holocene; palynology; Antarctica; vegetation; climate; South Georgia; Southern Westerlies

Late Quaternary dynamics of the Congo (Zaire) River plume: element ratios and planktonic foraminiferal evidence.

Els Ufkes[1], Colin Straathof[1] and Jan-Berend Stuut[1]

[1]VU University Amsterdam, Faculty of Earth and Life Sciences
*corresponding author: e.ufkes@vu.nl

The orientation and extent of the Congo River plume show a clear seasonal variability influenced by the African monsoon and is best expressed at its southern boundary by a distinct salinity gradient. Core T89-24, located at the southern boundary of the Congo River plume, will provide a detailed examination of processes steering the regional oceanographic conditions during the last 100 ka. Changes in the paleoceanographical conditions and precipitation over western and central Africa are modulated by orbital-scale and millennial-scale oscillations. In this study results from a planktonic foraminiferal sensus count record are combined with X-ray fluorescence measurements generated at 500-year and 50-year resolution respectively. Peaks in relative abundances of *Globigerinoides ruber* (pink), reflecting the proximity of the Congo River plume, are in phase with negative values in stable oxygen isotope record. Both proxies reveal millennial- to orbital-scale fluctuations in the river plume dynamics during the last 100 ka. However, the magnitudes of both proxies differ. The orientation of the Congo River plume is moreover steered by orbital-scale oscillations; a more northwestern orientation is reached during stadial and glacial periods.

Keywords: Planktonic foraminifera; XRF; Congo river plume; late Quaternary

Preservation and Reliability of geochemical Proxy Data from Foraminifera

J. Voigt[1]*, E. Hathorne[1] and M. Frank[1]

[1]GEOMAR Helmholtz Centre for Ocean Research Kiel, Wischhofstr. 1-3, 24148 Kiel, Germany
*corresponding author: jvoigt@geomar.de

The elemental and isotopic composition of foraminifera is widely used for reconstructing oceanic and climatic conditions in the past. However, ancient foraminiferal tests are altered after deposition through replacement of the original biogenic calcite by secondary (inorganic) calcite. Therefore, it is important to quantify changes in the elemental and isotopic composition of recrystallised tests to assess the reliability of proxy data. Here, we present results from a study of bulk carbonates, pore waters and foraminifera from IODP Expedition 320/321 Pacific Equatorial Age Transect (PEAT), where sediments of similar age and initial composition have been subjected to different diagenetic histories.

The geochemistry of bulk carbonates and associated pore waters suggest extensive recrystallisation at Site U1336 which has an enhanced thermal gradient. In sediments older than 20.3 Ma the $^{87}Sr/^{86}Sr$ ratios of Site U1336 bulk carbonates exhibit lower values than contemporaneous seawater indicating the incorporation of Sr originating from older carbonates. Furthermore, the generally lower Sr/Ca ratios of bulk carbonates from Site U1336 also suggest extensive recrystallisation.

Although the recrystallisation of bulk carbonates is well documented, the implications for the reliability of foraminiferal proxy data are unclear. To investigate this, laser ablation (LA) ICP-MS element/Ca ratio depth profiles through tests of the planktonic foraminifera *D. venezuelana* were obtained for specific time intervals from the PEAT Sites. Results reveal intra-test heterogeneity of Mg/Ca and Mn/Ca ratios whereas Sr/Ca ratios are mostly homogeneous through the test comparable to that reported for modern foraminifera (e.g. Hathorne *et al*. 2009). However, 56 % of all U1336 Sr profiles decrease by 0.2 mmol/mol from the outer to the inner calcite with the highest percentages for the older time intervals investigated. This indicates that recrystallisation can vary from individual to individual.

SEM images of the wall cross sections that were analysed by LA-ICP-MS suggest the tests from the Sites and time intervals have been recrystallised as the fine crystal structure seems to have been replaced by micron sized crystals. The images look similar for all Sites and time intervals whether Sr/Ca ratios change through the shell wall or not.

The LA-ICP-MS data for Mg/Ca and Mn/Ca ratios exhibit no systematic difference between the Sites and time intervals suggesting that foraminifera react differently from bulk carbonates during diagenetic recrystallisation. The results obtained from the foraminifera from the extensively recrystallised sediments indicate that much of the original geochemical proxy signals (Mg/Ca) is still preserved.

Keywords: recrystallization; foraminifera; Pacific Equatorial Age Transect; element/Ca ratios; laser ablation ICP-MS

REFERENCES

Hathorne E.C., James R.H., and Lampitt R.S. (2009) Environmental versus biomineralization controls on the intratest variation in the trace element composition of the planktonic foraminifera *G. inflata* and *G. scitula*. *Paleoceanography* 24, PA4204

Nannotax3 and Web delivery of Taxonomy

Jeremy R. Young*[1] Jacqueline A Lees[1] & Paul R. Bown[1]

[1]Dept. of Earth Sciences, University College London, Gower St., WC1E 6BT, London
*corresponding author: jeremy.young@ucl.ac.uk

The World Wide Web has revolutionised access to information enabling anyone to search for and hopefully find information on virtually anything. As a result, there is an increasing need to deliver reliable taxonomic data through the WWW. Students, non-specialist researchers, and indeed even expert taxonomists working outside their areas of specialisation increasingly expect to find answers via the web rather than from traditional monographs. Moreover, some students may even trust answers found via the internet more than from printed publications. So, there is a general need to deliver reliable taxonomic data via the web, and this certainly applies to micropalaeontology which has numerous users and widely scattered literature much of which is accessible only via academic libraries or expensive subscriptions.

Nannotax is an online database of nannofossil taxonomy and images, which we have been developing since 2007. Initial development was as a Scratchpads website within the EU EDIT project. Funding from an NERC Knowledge Exchange grant has allowed us to considerably expand the project and after some software problems it is now running as a php-scripted website, at ina.tmsoc.org/Nannotax3. The system currently includes 2500 species, providing near-comprehensive coverage of extant coccolithophores and nannofossils. It includes diagnoses and stratigraphic ranges of most taxa, extended descriptions of some, and >10,000 images. A novel tabular layout is used to summarise the content of higher taxa and allow rapid taxonomic browsing. This layout also makes it an effective tool for learning and teaching nannofossil taxonomy. In addition filtering by geological age allows users to focus their search on the taxa occurring within any time interval.

IODP strongly endorsed the development of the project and a copy of the website should be installed on the JOIDES Resolution and Chikyu by the time of the conference.

Keywords: nannofossils; coccolithophores; taxonomy; knowledge transfer

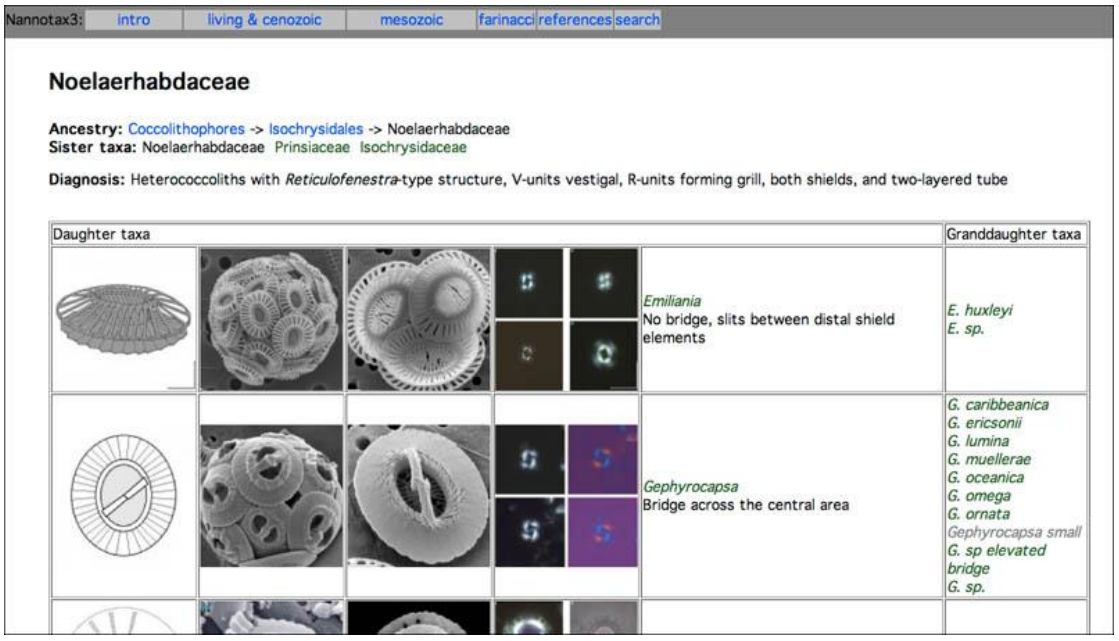


Figure 1: screenshot of the Nannotax online database

A mysterious Bulimina in Upper Cretaceous trace fossils from Southern France: possible relicts of the Cretaceous/Paleogene impact?

Laia Alegret[1]*, Francisco J. Rodríguez-Tovar[2] and Alfred Uchman[3]

[1]Dept. Ciencias de la Tierra & IUCA, Universidad de Zaragoza, Zaragoza, Spain
[2]Dept. Estratigrafía y Paleontología, Universidad de Granada, Granada, Spain.
[3]Jagiellonian University, Institute of Geological Sciences, Kraków, Poland
*corresponding author: laia@unizar.es

Trace fossils are relatively abundant across the Cretaceous/Paleogene (K/Pg) boundary interval, and they may obscure the micropaleontological record across this interval because microfossils are easily redistributed within the sediment passively by falling into the burrow or actively by the tracemaker action. In order to assess the role of tracemakers in the redistribution of benthic foraminifera across the K/Pg interval, we analysed trace fossil infillings and their background sediment in the upper-middle bathyal Bidart section (SW France).

The micropaleontological analyses allowed us to infer pre- and post-K/Pg boundary colonization phases, and to identify infiltration of Paleogene benthic foraminifera into Cretaceous sediments. Furthermore, our results pose questions about the completeness of the K/Pg boundary transition. Assemblages from dark-filled *Thalassinoides* are very different from the assemblages recognized in the background sediment, and they contain very abundant *Bulimina* sp. 1, a species that to our knowledge has never been identified neither in Upper Cretaceous nor in Paleogene sediments. We speculate that *Bulimina* sp. 1 might have colonized the seafloor during a period of high export productivity right after the K/Pg boundary, as suggested by the occurrence of dinoflagellate blooms and eutrophic planktic foraminiferal and calcareous nannofossil assemblages.

We conclude that detailed analysis of trace fossil infillings must not be overlooked in micropaleontological studies, as these may contain information on time intervals that are no longer represented in the stratigraphic record. The combined study of trace fossils and benthic foraminifera reveals as a powerful tool in eco-stratigraphy and event-stratigraphy.

Keywords: Bioturbation; Cretaceous/Paleogene interval; benthic foraminifera

Appraisal of benthic foraminiferal assemblages across hyperthermal events at ODP Site 865

G. J. Arreguín-Rodríguez[1], L. Alegret[1]* and E. Thomas[2]

[1]Departamento de Ciencias de la Tierra, Universidad de Zaragoza, Zaragoza, Spain
[2]Department Center for the Study of Global Change, Department of Geology and Geophysics, Yale University, USA
*corresponding author: laia@unizar.es

The greenhouse climate of the early Paleogene was interrupted by short-lived global warming events, known as hyperthermals, which were associated with the release of isotopically depleted carbon into the ocean-atmosphere system, potential de-oxygenation, ocean acidification and perturbations of the hydrological cycle and biotic associations. In order to understand the response of benthic foraminifera to the early Eocene hyperthermals, we analyzed their assemblages from the ODP Site 865 at Allison Guyot on the equatorial Pacific. We focused our study on the Paleocene Eocene Thermal Maximum (PETM) and the Eocene Thermal Maximum-3 (ETM3) events because these are the only hyperthermals that were confidently identified due to the low sedimentation rates.

The ratio between calcareous and agglutinated taxa and the percentage of $CaCO_3$ suggest that dissolution was not severe during both hyperthermal events. Infaunal morphogroups, mainly composed of cylindrical taxa, dominate the assemblages through the whole studied interval, and peaked during the PETM and immediately after the ETM3. Bolivinids and buliminids show the same pattern. The high percentage of infaunal taxa is unexpected in an oligotrophic setting, however, and may result from the interaction between food supply and currents over the guyot-top, which allowed the enrichment of infaunal taxa with suspension-feeding strategies while epifaunal taxa could not persist in the currents. Among cylindrical taxa, "smooth" forms (lagenids, pleurostomellids) were less common than spiny forms (stilostomellids) at Site 865, but more common than at high latitude sites, and they might have been living deeper infaunally (Mancin *et al*., 2013).

The PETM and ETM3 events show similar characteristics at Site 865, displaying negative shifts in $\delta^{13}C$ and similar faunal turnover of the benthic assemblages, although the magnitude of changes was significantly larger during the PETM than in the ETM3.

Keywords: benthic foraminifera; hyperthermal events; PETM; ETM3.

REFERENCES

Mancin, N., Hayward, B. W., Trattenero, I., Cobianchi, M., Lupi, C., 2013. Can the morphology of deep-sea benthic foraminifera reveal what caused their extinction during the mid-Pleistocene Climate Transition? *Marine Micropaleontology*, 104: 53-70.

Exceptional records of calcareous nannoplankton biodiversity across the Palaeocene-Eocene Thermal Maximum (PETM) from US shelf sections

*Daniel Austin[1], Samantha Gibbs[1], Richard Pierce[1], Paul Bown[2]

[1]Ocean and Earth Science, University of Southampton, National Oceanography Centre, Southampton United Kingdom, dma1g08@alumni.soton.ac.uk
[2]Department of Earth Sciences, Faculty of Maths & Physical Sciences, University College London, London, United Kingdom
*corresponding author: daniel.m.austin@gmail.com

Studies of calcareous nannoplankton have provided valuable insights into the Palaeocene-Eocene Thermal Maximum (PETM), a transient greenhouse interval resulting from a sudden perturbation of the carbon cycle comparable to predicted changes for the next century due to anthropogenic global warming. The geological record of the PETM provides evidence for disruption of the deep oceans, evidenced by a shoaling of the lysocline and mass extinction of benthic foraminifera. By contrast the response of the surface oceans appears to be more muted with evidence for poleward range shifts, the appearance of short-lived excursion taxa and slightly elevated turnover rates observed in the nannoplankton fossil record.

Recent studies of exceptionally preserved assemblages from Tanzania may suggest that this signal is in part the result of the quality of the fossil record. Records from Tanzania contain nannofossil diversity consistently higher than any other site previously studied and record several previously unrecorded species. Much of this additional diversity was supplied by specific groups that are known to be dissolution susceptible or fragile such as rhabdoliths and holococcoliths. Our study explores similarly preserved material from the PETM but from Bass River, New Jersey and Lodo Gulch, California, two sites geographically removed from Tanzania

Using scanning electron microscopy to investigate rock chip samples of hemipelagic mudstones we recorded a rich diversity of calcareous nannoplankton, rarely preserved biological associations and cryptic speciation patterns. Much of the new diversity is composed of fragile and dissolution susceptible taxa; particularly species of holococcoliths.

We also observe several examples of taxa not previously observed outside of Tanzania such as *Braarudosphaera perampla* and *Kilwalithus*. Nannofossils at both sites frequently contain immaculately preserved microstructures and biological associations including intact coccospheres, complex morphologies and protococcolith rings.

Our results indicate that both sites preserve exceptionally diverse nannoplankton communities which are indicative of two different palaeoenvironments. Whereas the assemblage from Lodo Gulch indicates a heavily stratified oligotrophic regime with much of the productivity limited to the surface waters, the floral assemblage at Bass River appears to be controlled by seasonal nutrient fluxes resulting from an intensified hydrological cycle.

The resulting phytoplankton blooms have preserved near complete ontogenetic sequences for *Towieus* sp. and *Coccolithus pelagicus* as well as morphometric evidence for species specific growth responses to the PETM.

Keywords: Calcareous Nannofossils; PETM; Diversity; Palaeocene; Eocene

Field and culture-based calibration of salinity and temperature proxies from benthic foraminifera: Meeting the challenges of ECORD/IODP Expedition 347

WEN Austin[1,2], HL Filipsson[3], DJ McCarthy[1], K Darling[4], C.Bird[4], J Groeneveld[5], M. Schweizer[4,6]

[1]School of Geography & Geosciences, University of St Andrews, St Andrews, Fife, Scotland, UK.
[2]Scottish Association for Marine Science, Scottish Marine Institute, Oban, Argyll and Bute, Scotland, UK.
[3]Department of Geology, Lund University, Sölvegatan 12, SE-223 62 Lund, Sweden.
[4]Grant Institute of Earth Science, School of GeoSciences, University of Edinburgh, West Mains Road, Edinburgh, Scotland, UK.
[5]Department of Geosciences, University of Bremen, Klagenfurter Straße, Room 5540 Geo-Building, D-28359 Bremen, Germany.
[6]LUNAM Université - Université d'Angers, LPG-BIAF, CNRS UMR 6112, 2 Boulevard Lavoisier, 49045 Angers Cedex, France.
*corresponding author: wena@st-andrews.ac.uk

Some of the most significant challenges in palaeoclimate research arise from the need to both understand and reduce uncertainty associated with proxy variable methods. This is especially important for shelf and coastal environments where increasing numbers of high-resolution palaeorecords are being generated that are likely to be characterised by greater environmental variability. These challenges are further highlighted in connection with the current ECORD/IODP expedition 347: Baltic Sea Paleoenvironment. This large-scale drilling operation is currently underway in the Kattegat and the Baltic Sea (Autumn 2013) and is expected to recover sediments spanning the last 150,000 years and encompassing the last interglacial-glacial cycle. There is therefore an urgent need for proxy calibrations directly targeting the brackish Baltic Sea environment, calibrations which are currently lacking.

We are investigating different temperature and salinity proxy variables through a combination of field- and culture-based foraminiferal samples, together with genetic characterization (genotyping) of the morphospecies. We are running a field campaign where we collect live foraminiferal samples as well as water samples at two sites: fully marine Anholt, Kattegat and low salinity Hanöbay, Baltic Sea. The bottom water salinity during our first sampling campaign ranged from 14 to 33 psu and, and the temperature between 5 and 9°C. The core top samples are in the process of being analysed for trace-metals, $\delta^{18}O$, $\delta^{13}C$, and benthic foraminiferal faunal composition. Live foraminifera collected from the sediment-water interface are also being cultured in seawater at a constant temperature of 10°C and at three different salinities (15, 25, 31 psu). The culturing system contains three 400 L seawater tanks at set salinities, each connected to multiple culture chambers in a recirculating seawater system. We plan to perform trace element and isotope analyses on the resulting foraminiferal yield. Furthermore, genotyping work is being carried out to minimize the effects of taxonomic uncertainty and (pseudo)-cryptic species-effects. We will present and discuss the latest results from the project, highlighting their potential value to meeting Expedition 347 objectives.

Late Pleistocene palaeoceanographic conditions and monsoon variability in the Bay of Bengal from LA-ICPMS depth profiles of planktonic foraminifera

R. Bhatia[1]*, D. Evans[1], H. Stoll[2] & W. Müller[1]

[1]Department of Earth Sciences, Royal Holloway University of London, Egham, Surrey, TW20 0EX, United Kingdom,
[2]Dept de Geologia, Universidad de Oviedo, 33005 Oviedo, Spain
*corresponding author: rehemat.bhatia.13@ucl.ac.uk

The Bay of Bengal is heavily influenced by freshwater input, mainly from the seasonally varying Indian Monsoon, which alters seawater chemistry and conditions. Via new Mg/Ca derived palaeo sea surface temperatures (SST) coupled with existing $\delta^{18}O$ data of the same samples (Stoll *et al*., 2007) we aim at reconstructing Indian monsoon variability during the late Pleistocene (12,800 – 181,000 ka) from core RC12-343 (central Bay of Bengal).

Mg/Ca measurements of individual chambers of the planktonic foraminifera species *Globigerinoides ruber* were obtained using slow depth profiling utilising laser ablation inductively coupled mass spectrometry (LA-ICPMS). The oxygen isotopic composition of seawater ($\delta^{18}O_{sw}$) was calculated from combined Mg/Ca SST and published $\delta^{18}O$ datasets (Stoll *et al*., 2007 & Chen & Farrell, 1991) using the palaeotemperature equation of Erez & Luz (1983). Scanning electron microscopy and trace element (Mn, Al & Y) chemistry of the foraminiferal tests were used to assess sample preservation.

Aside from tests which were well preserved, there were 3 main styles of test preservation in the core. Tests contained features of dissolution, secondary recrystallisation and partial recrystallisation; each style had diagnostic trace element chemistry, identified by Mn, Nd, Al, Mg & Y concentrations. Our initial Mg/Ca data suggest that sea surface temperatures in the late Pleistocene were up to 4°C cooler than the present day. Temperatures calculated were between 23.2°C and 25.81°C. Corresponding results on monsoon variability via reconstructed $\delta^{18}O_{sw}$ will be presented.

Keywords: foraminifera; geochemistry; palaeoclimate; Pleistocene

REFERENCES

Chen M.T. & Farrell J. (1991) “4. Planktonic foraminifer faunal variations in the Northeastern Indian Ocean: A high-resolution record of the past 800,000 years from site 758”, in: Weissel J, Peirce J, Taylor E, Alt J *et al*., (1991), *Proceedings of the Ocean Drilling Program*, Scientific Results, 121

Erez J. & Luz B. (1983) “Experimental paleotemperature equation for planktonic foraminifera”, *Geochimica et Cosmochimica Acta*, 47, 1025 – 1031

Stoll H.M., Vance D. & Arevalos A. (2007) “Records of the Nd isotope composition of seawater from the Bay of Bengal: Implications for the impact of Northern Hemisphere cooling on ITCZ movement*”, Earth and Planetary Science Letters*, 255, 213 – 255

Long-term algal adaptation to changing climate over the Neogene: integrating coccolith geochemical and morphological records

C.T. Bolton[1]*, M.-A. Fuertes[2], H.M. Stoll[1] and J.A. Flores[2]

[1]Geology Department, University of Oviedo, Asturias, 33005, Spain
[2]Oceanic Geoscience Group, Science Faculty, University of Salamanca, Spain
*corresponding author: cbolton@geol.uniovi.es

Long term adaptation of phytoplankton to decreasing carbon dioxide (CO_2) has resulted in modern algae capable of actively enhancing CO_2 at the site of photosynthesis. Coccolithophores, calcifying marine algae of the class Prymnesiophyceae, uniquely preserve the geological history of this adaptation because the stable carbon and oxygen isotopic compositions ($\delta^{18}O$ and $\delta^{13}C$) of their calcite plates (coccoliths) are sensitive to active carbon uptake and transport by the cell. Cultures of coccolithophores grown under ambient, CO_2-limiting conditions show an unusually large array (up to 5 ‰) of size-correlated $\delta^{18}O$ and $\delta^{13}C$ compositions or 'vital effects', which are also evident in coccoliths from Plio-Pleistocene sediments. Conversely, the isotopic difference between small and large coccoliths diminishes in cultures grown at elevated CO_2 and is absent in fossil coccoliths from past Palaeocene greenhouse climates. Here, we constrain the timing of the Cenozoic emergence of coccolith vital effects in the fossil record and its relationship to climate evolution and the long-term decrease in $_pCO_2$. We present new records of $\delta^{18}O$ and $\delta^{13}C$ from size-separated coccoliths that document a step increase in the range of vital effects between small and large coccoliths during an interval of significant global cooling at two widely spaced sites (Caribbean Sea and South Atlantic). Using a new cellular model, we show that the emergence of coccolith vital effects in the geological record could stem from a threshold adaptive response of cells to CO_2 limitation. In order to investigate a potential calcification response that may have occurred in parallel to an increase in the range of coccolith stable isotope fractionations, we also present a new record of Noelaerhabdacae coccolith mass and morphology over the same interval from the Indian Ocean.

Keywords: coccolithophores; carbon dioxide; adaptation; coccolith mass; stable isotopes; Miocene.

Impact of latest Cretaceous to earliest Paleogene climate and environmental change on Antarctic Peninsula vegetation

V.C. Bowman[1]*, J.E. Francis[1], R.A. Askin[2], J.B. Riding[3] and G.T. Swindles[4]

[1]Environmental Change and Evolution, British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 0ET, U.K.
[2]Jackson, Wyoming, U.S.A.
[3]British Geological Survey, Keyworth, Nottingham, NG12 5GG, U.K.
[4]School of Geography, University of Leeds, Leeds, LS2 9JT, U.K.
*corresponding author: vanwma@bas.ac.uk

Late Cretaceous climates were relatively cool and dynamic following mid Cretaceous warmth, and may have generated ephemeral ice sheets on Antarctica. These fluctuations in climate were already significantly influencing biotic change prior to the Cretaceous/Paleogene (K-Pg) catastrophe, but their general nature, magnitude and timing remain controversial. We present a high-resolution dataset of terrestrially-derived palynomorphs from an expanded latest Cretaceous to earliest Paleogene shallow marine sedimentary succession from Seymour Island (James Ross Basin, Antarctic Peninsula), then, as now, located at ~65°S. Using modern analogue techniques, we present the first detailed vegetation, habitat and climate reconstruction for the emergent volcanic arc at this time, thereby unlocking details of small-scale climate variability at the high southern palaeolatitudes.

Cool to warm temperate rainforest covered the coastal lowlands within a riverine landscape. Diverse podocarps and southern beech trees grew alongside aromatic angiosperm herbs and shrubs, and high altitude araucarian forests and ericaceous heathland thrived near the tree line (Fig. 1). There is no exact modern botanical equivalent, but the closest modern flora is the Andean forest of southern Chile and Argentina. Maastrichtian climate is shown to have fluctuated from cool, humid conditions, through a rapid warming ~2 millions years prior to the K-Pg transition, followed by cooling during the earliest Danian, a trend supported by previous work on this interval. The data herein provide unprecedented detail from a terrestrial proxy akin to marine oxygen isotope records.

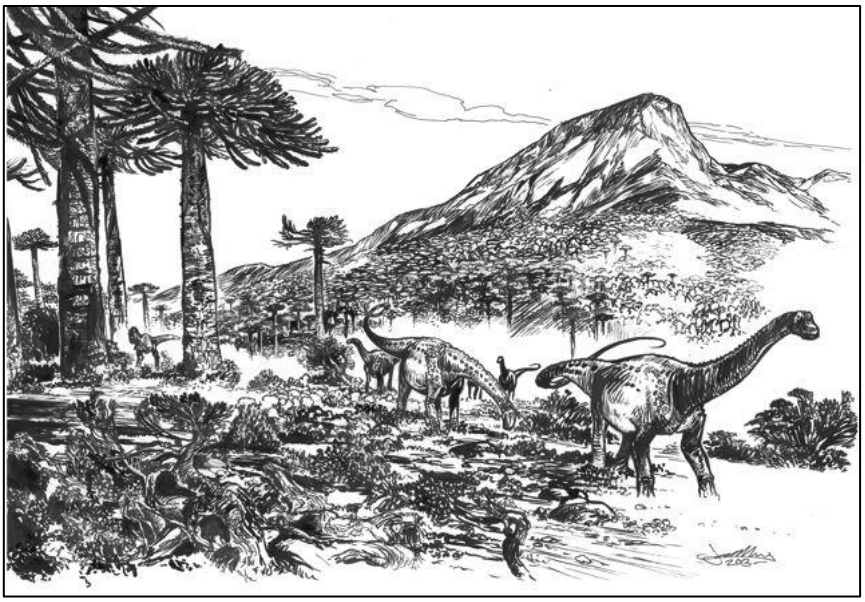


Figure 1: Reconstruction of high-altitude vegetation on the Antarctic Peninsula, Maastrichtian and earliest Danian. At the tree line, araucarian-dominated forest stands may have bordered well-drained montane heaths. Fragments of theropod and sauropod dinosaurs are known from Late Cretaceous sediments in the James Ross Basin (e.g. Cerda *et al*., 2012). Artist: James McKay, j.mckay@leeds.ac.uk.

Keywords: Cretaceous; Maastrichtian; Antarctica; terrestrial palynomorphs; palaeoclimate; vegetation reconstruction

REFERENCES

Cerda, I.A., Carabajal, A.P., Salgado, L., Coria, R.A., Reguero, M.A., Tambussi, C.P., Moly, J.J., 2012. The first record of a sauropod dinosaur from Antarctica. *Naturwissenschaften*, 99, 83-87.]

Antarctic Margin, Wilkes Land, Calcareous Nannofossil Assemblages across the Greenhouse-Icehouse Transition

Aisling Broderick[1]

[1]Earth Sciences, School of Geography, Earth & Environmental Sciences, University of Birmingham, Birmingham, UK

*corresponding author: AJB243@bham.ac.uk

Site U1356 is located on the margin of Wilkes Land, Antarctica. The main target of drilling at the site was a regional unconformity referred to as WL-U3. There were three aims of this project, firstly to present, for the first time, calcareous nannofossils assemblages at the Wilkes Land, Antarctic margin. The second aim of this project was to constrain the age of strata underlying and above the WL-U3 unconformity using calcareous nannofossils and lastly to establish any differences between Eocene and Oligocene assemblages. Smear slides were made in the standard method for 31 samples and were analysed using a GT Vision, GXM XPL3200 polarising microscope and photographed using Ziess Scope A1 microscope and Q Imaging QICam camera. Biostratigraphy for the site based on calcareous nannofossils has dated the strata below the unconformity at ~39Ma and the strata above the hiatus is dated ~33.6Ma. The Eocene assemblages are mostly composed of warm and temperate water taxa such as *Coccolithus formosus, Spenolithus moriformis* and Reticulofenestra bisecta, whereas Oligocene assemblages are dominated by cold and temperate water *taxa for example Chiasmolithus* spp*., R. daviesii and R. bisecta*. Therefore there is a distinct shift in calcareous nannofossils assemblages from Eocene to Oligocene. Despite the change in nannofossil assemblages, species diversity does not vary greatly between the Eocene and Oligocene.

Keywords: Eocene; Oligocene; Calcareous Nannofossils; Southern Ocean; Wilkes Land

Utilizing legacy cores to complement new drilling: A re-examination of ODP Site 1073 Pleistocene stratigraphy

B. A. Christensen[1]* and C. Smart[2]

[1]Adelphi University, Garden City, NY 11530 USA;
[2]Plymouth University, Plymouth, Devon, PL4 8AA, UK
*corresponding author: christensen@adelphi.edu

ODP Leg 174A Site 1073 (639 m w.d.), is a potentially excellent record of glacial- interglacial change on the upper NJ continental slope. The very high sedimentation rate allows the site to be used as a complement to recent shelf drilling, and may hold clues to the timing and pattern of depositional environment that was removed by incision and erosion during glaciation.

Recent work on the NJ shelf shows that incision occurred around the LGM, and was followed by rapid sea level rise and infilling of the channels incised during stadials. The cross-shelf incisions suggest NJ rivers played a strong role in delivering meltwater during deglaciation. Recent investigations into the mineralogy suggest it is possible to refine the source (e.g., NJ vs. Hudson Valley). If meltwaters were delivered by multiple river systems rather than focused on the Hudson, then this has implications for volume of water delivered to the region during the Younger Dryas, and the hypothesized impacts on the Gulf Stream and NADW.

However, evaluation of the nature of glaciation on the continental slope requires a detailed stratigraphy. The original stratigraphy was based on biostratigraphy and limited carbon-14 dating. Re-evaluation suggests additional interpretations are possible. The alternative stratigraphies reconcile some of the previous inconsistencies between the slope sites drilled on Leg 174 and the earlier Leg 150 sites, which are missing sediments from Stages 5 through 2.

Keywords: New Jersey; continental slope; stratigraphy

Ordovician Radiolarian paleogeographic distribution: patterns, paleobiogeographic significance and limitations

T. Danelian[1]*, P. Noble[2], L. Pouille[1] and J. Maletz[3]

[1]University Lille 1, Géosystèmes, Department of Earth Sciences, Villeneuve d'Ascq, France;
[2]Department of Geological Sciences & Engineering, University of Nevada Reno, MS 172, Reno, USA;
[3] Institut für Geologische Wissenschaften, Freie Universität Berlin, Malteserstr. 74-100, D-12249 Berlin, Germany
*corresponding author: Taniel.Danelian@univ-lille1.fr

Over the past 15 years, significant progress has been achieved in our understanding of Lower Palaeozoic radiolarian faunas. However, description of biogeographic patterns of Ordovician Radiolaria is hampered by the paucity of known occurrences as well as possible taphonomic influences. The distribution of all known assemblages is analysed in time and space. Lower Ordovician (especially Tremadocian) Radiolaria are known from two distinct tropical localities of Laurentia. Geographic coverage is much better for the Middle Ordovician (Darriwilian). However, data are concentrated in tropical palaeolatitudes (between 30°N and 30°S). The absence of data from mid/high latitude localities limits any biogeographic insights. In addition to this there are taphonomic and taxonomic biases. Data are also sparse for the Upper Ordovician. However, comparison between Australian and Nevadan material of Katian age shows strong similarities suggesting the presence of a coherent tropical radiolarian bioprovince, as in the modern ocean.

Keywords: Radiolaria; Ordovician; paleobiogeography.

Benthic foraminiferal and isotopic patterns during the Early Eocene Climatic Optimum (Aktulagay section, Kazakhstan)

Arne Deprez[1]*, Steven Tesseur[1], Peter Stassen[1], Simon D'haenens[1], Etienne Steurbaut[1,2], Christopher King[3], Philippe Claeys[4] and Robert P. Speijer[1]

[1]Department of Earth and Environmental Sciences, KU Leuven, Celestijnenlaan 200E, B-3001 Leuven, Belgium [2]Department of Paleontology, Royal Belgian Institute of Natural Sciences, Vautierstraat 29, B-1000 Brussels, Belgium
[3]16A Park Rd., Bridport DT6 5DA, United Kingdom
[4]Earth System Science, Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussels, Belgium
*corresponding author: arne.deprez@ees.kuleuven.be

The early Eocene is characterized by long-term global warming culminating in the Early Eocene Climatic Optimum (EECO). During this time interval, of which previously only the PETM was intensively studied, the Peri-Tethys was characterized by its position between north-south and east-west trending seaways. The Aktulagay section in Kazakhstan provides an expanded record of the middle Ypresian (NP11-13, ~54-50 Ma), covering the lower part of the EECO. It features a series of sapropel beds, observed throughout the Peri-Tethys. In order to unravel paleoenvironmental changes, we carried out quantitative faunal studies and isotopic investigations on excellently preserved foraminiferal assemblages.

The period from 54 to 52 Ma is characterized by a diverse assemblage of deep outer neritic benthic foraminifera, with common *Pulsiphonina prima* and *Paralabamina lunata*. Coupled negative carbon and oxygen isotope excursions point to hyperthermals occurring during this time interval, but these are not evident from the faunal or sedimentological record. The initially (54 Ma) well-ventilated oligo- to mesotrophic sea floor conditions gradually change to more eutrophic and oxygen-limited. This gradual onset culminates in permanent stratification in the sapropel-bearing unit around 52 Ma, with the dominance of *Anomalinoides acutus* and *Bulimina aksuatica*. The absence of ostracods and abundance of hematitic concretions are consistent with this interpretation. Rising $\delta^{13}C_{endobenthic}$ indicate migration of endobenthic species to the sediment-water interface. Benthic foraminiferal assemblages dominated by *Epistominella minuta* at ~51-50 Ma indicate a highly seasonal food supply and episodic disruption of stratification. Dinoflagellate blooms and *Acarinina* isotope values at 20.25 m indicate lower salinity (lower $\delta^{18}O$) and higher productivity (higher $\delta^{13}C$), possibly due to riverine input. This coincides with the peak of the EECO, as indicated by its position close to the base of NP13 and rising $\delta^{13}C_{foram}$ values. Although it is tempting to link the observed patterns to climate change, we can currently not exclude that changing paleogeography and variable connections to the Tethys, Atlantic and the Arctic ocean largely determined the long-term period of dysoxia and anoxia during deposition of the sapropel beds at the Peri-Tethyan seafloor. These rapid, small biofacies shifts observed in the Aktulagay section may reflect a stepwise transition in long-term re-shaping of benthic foraminiferal communities.

Keywords: Eocene; benthic foraminifera; stable isotope; paleoecology; Kazakhstan; oxygen deficiency; trophic conditions

A North Atlantic perspective of Eocene Thermal Maximum 2 (ETM2)

Simon D'haenens[1]*, André Bornemann[2], Philippe Claeys[3], Jeroen Groeneveld[4], Ursula Röhl[5], Etienne Steurbaut[6], Robert P. Speijer[1]

[1]Department of Earth and Environmental Sciences, KU Leuven, Belgium
[2]Institut für Geophysik und Geologie, Universität Leipzig, Germany
[3]Earth System Science, Vrije Universiteit Brussel, Belgium
[4]Fachbereich für Geowissenschaften, Universität Bremen, Germany
[5]MARUM – Zentrum für Umweltwissenschaften, Universität Bremen, Germany
[6]Department of Paleontology, Royal Belgian Institute of Natural Sciences, Belgium
*corresponding author: Simon.Dhaenens@ees.kuleuven.be

ETM2 is considered as the "little brother" of the PETM as it displays similar but less intense global warming, ocean acidification and biotic shifts. However, the global heterogeneity of ETM2 may be underestimated, severely influencing early Eocene climate models. We investigate hyperthermal events ETM2 and H2 in the NE Atlantic (DSDP Sites 401 and 550; ~2 km and ~4 km paleodepth, respectively) using multispecies foraminiferal $\delta^{18}O$ and $\delta^{13}C$.

The incorporation of new and published XRF core scanning data in the isotope records allows for a stratigraphic correlation of Site 401 with the astronomically tuned Site 550, confirming the position of ETM2. We find that the CIE for ETM2 at abyssal Site 550 is ~1.10‰ for *Nuttallides* and *Oridorsalis* while smaller amplitudes of ~0.85‰ are recorded at bathyal Site 401. δ18O-derived bottom water temperatures are uniform suggesting that both sites were bathed by a similar water mass. A comparison of Atlantic benthic $\delta^{13}C$ patterns and the incorporation of grain size analysis indicate a transient switch in bottom-water circulation during ETM2.

Planktic foraminifera (*Morozovella*, *Acarinina* and *Subbotina*) on the other hand, register CIEs >1.50‰. Complex planktic $\delta^{18}O$ and Mg/Ca patterns leading into ETM2 suggest a gradual return to fully marine surface water conditions following a post-PETM interval of enhanced regional run off, freshening surface waters. The contemporaneous >50% reduction in clay supply supports this hypothesis and a shift in the regional evaporation-precipitation balance is inferred.

Planktic assemblages of Site 401 and preliminary benthic counts of Site 550 corroborate the short- and long-term benthic assemblage changes that track the effects of the ETM2 (= level δ in D'haenens *et al*., 2012). Our findings imply that the evolution of these sensitive marine ecosystems is shaped by the short-and long-term consequences of the ETM2.

Keywords: Hyperthermal; benthic foraminiferal stable isotopes; planktic foraminifera; benthic foraminifera; grain size analysis; calcite compensation depth; North Atlantic Ocean.

REFERENCES

D'haenens, S., A. Bornemann, P. Stassen, R. P. Speijer (2012), Multiple early Eocene benthic foraminiferal assemblage and δ13C fluctuations at DSDP Site 401 (Bay of Biscay — NE Atlantic), *Marine Micropaleontology* 88-89, 15–35.

Testing the impact of diagenesis on the $\delta^{11}B$ and trace element geochemistry of planktic foraminiferal calcite

K.M. Edgar[1]*, E. Anagnostou[2], P.N. Pearson[1], G.L. Foster[2] , E.H. John[1] & C.H. Lear[1]

[1]School of Earth and Ocean Sciences, Cardiff University, UK
[2]Ocean and Earth Science, National Oceanography Centre Southampton, UK
*corresponding author: edgark1@Cardiff.ac.uk

The geochemical composition of foraminiferal tests is a valuable archive for the reconstruction of palaeo-climatic, -oceanographic and -ecological changes. However, dissolution of biogenic calcite and re-precipitation of inorganic calcite (overgrowth and recrystallisation) at the seafloor and in the sediment column can potentially alter the original geochemical composition of the foraminiferal test, biasing any resulting palaeoreconstructions.

A wealth of new carbonate-based proxies are increasingly utilised to understand the ancient Earth and in particular unravel the complexities of the carbonate system (e.g., $\delta^{11}B$, B/Ca and Li/Ca) but the effect of diagenesis on these proxies is not well known. Here we present new $\delta^{11}B$ and element/calcium data in multiple planktic foraminiferal species from two time-equivalent sedimentary settings with different diagenetic histories (carbonate-rich ODP Site 865 and clay-rich TDP Site 18). Although nearly identical Eocene planktic foraminiferal assemblages are found at these two tropical sites, foraminiferal tests from ODP Site 865 have a typical recrystallised or “frosty” appearance whereas those at TDP Site 18 have experienced little or no recrystallisation and have a “glassy” appearance. We exploit this taphonomic contrast to constrain the impact of diagenesis on these isotopic and trace element proxies.

Keywords: diagenesis; planktic foraminifera; Integrated Ocean Drilling Program; $\delta^{11}B$.

Ocean's $\delta^{13}C$: A new high resolution planktonic foraminiferal stable isotope record from the Equatorial Pacific Ocean (IODP Site U1338)

Lyndsey Fox[1]*, Bridget Wade[2], Ann Holbourn[3] & Melanie Leng[4]

[1]School of Earth and Environment, University of Leeds, Leeds, LS2 9JT.
[2]Department of Earth Sciences, University College London, Gower Street, London, WC1E 6B,UK.
[3]Institut für Geowissenschaften Christian-Albrechts-Universität zu Kiel, Ludewig-Meyn-Straße 14, 24118 Kiel, Germany.
[4]NERC Isotope Geosciences Laboratory, Kingsley Dunham Centre, Keyworth, Nottingham, NG12 5GG, UK.
*corresponding author: eelrf@leeds.ac.uk

The middle Miocene (17-13.5 Ma) was the warmest interval of the Neogene. During the early to middle Miocene the climate fluctuated greatly, with cyclic periods of Antarctic glaciation and climatic warming termed the "mid Miocene climate optimum" characterised by a negative oxygen isotope excursion.

Detailed planktonic foraminiferal geochemical records are crucial to any reconstruction and modelling of past ocean salinity and density, water column stratification, thermohaline circulation, and ice volume. Despite extensive studies of benthic foraminifera, existing planktonic foraminiferal records of this interval are extremely scarce and of low resolution. Consequently the impact of global warming and cooling on tropical surface waters and the propagation of orbital cycles in the Earth System are unknown.

Integrated Ocean Drilling Program Expedition 320/321 recovered lower-middle Miocene sediments with high sedimentation rates (30m/myr), continuous recovery, and orbital cyclicity from the equatorial Pacific. Previous studies of the lower Miocene interval have been hindered by the absence of biogenic carbonate (e.g., Leg 199). At Site U1338 planktonic foraminifera are abundant and diverse in the lower and middle Miocene sediments and exceptionally well preserved. Scanning electron microscope studies revealed open pore spaces, little evidence of calcitic overgrowth on the wall surface and in many cases preserved spines (Fox and Wade, in press).

We present the first high-resolution (3 kyr) astronomically-tuned record of $\delta^{18}O$ and $\delta^{13}C$ from planktonic foraminifera for the equatorial Pacific Ocean (16.5–13.5 Myr), as well as an overview of foraminiferal assemblages from the middle Miocene, examining the preservation and potential for future studies of foraminiferal evolution.

REFERENCES

Fox, L. R., and Wade, B. S., 2013, Systematic taxonomy of Early-Middle Miocene planktonic foraminifera from the equatorial Pacific Ocean: Integrated Ocean Drilling Program, Site U1338; *Journal of Foraminiferal Research*, v. 43, no. 4, p. 373–40.

Long-term evolution of Cenomanian to Campanian black shale formation at Demerara Rise

O. Friedrich[1]*, J. Erbacher[2], R.D. Norris[3] & B. Beckmann[4]

[1]Institut für Geowissenschaften, Universität Heidelberg;
[2]Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover
[3]Scripps Institution of Oceanography, University of California, San Diego
[4]MARUM, Universität Bremen
*corresponding author: o.friedrich@em.uni-frankfurt.de

We present a 20 Million year record of benthic foraminiferal assemblage data spanning the Cenomanian to Campanian black shale sequence at Demerara Rise, tropical Atlantic (ODP Leg 207). This location is characterized by a continuous formation of organic-rich sediments (black shales) that have mean TOC values of 5-10 %, peaking at the OAE2 event (up to 30%). Interestingly, however, benthic foraminifera are present during a long time within these sediments, suggesting large fluctuations in bottom-water ventilation and oxygenation.

We combine this long-term benthic assemblage record with stable isotope, Nd isotope and TOC records from the same sites and can show that there are several periods of ventilation that occur, interestingly, during major events in the Cenomanian and Turonian (1) the OAE2 interval and (2) during a proposed glaciation event in the Late Turonian.

From the Coniacian onwards, there is clear evidence for a stepwise change in bottom-water characteristics towards higher oxygen availability, that we interpret to reflect the beginning influence of opening the Equatorial Atlantic gateway and therefore the inflow of cooler, better oxygenated water masses.

After a large hiatus in the early Campanian, the middle Campanian shows assemblages typical for the Late Cretaceous Atlantic, indicating normal marine conditions.

Keywords: Cretaceous; benthic foraminifera; OAE.

The relationship between retreat of the East Antarctic ice sheet and CO2 during the Mid-Miocene Climatic Optimum.

R. Greenop[1]*, G.L. Foster[1], P.A. Wilson[1], C.H. Lear[2]

[1]National Oceanography Centre, Southampton, University of Southampton Waterfront Campus, European Way, Southampton SO14 3ZH
[2]Cardiff University, School of Earth & Ocean Sciences, Cardiff, CF10 3AT
*corresponding author: R.Greenop@noc.soton.ac.uk

The output from ice sheet modeling experiments suggest that once large ice sheets have grown on East Antarctica they are inherently stable as a result of a powerful hysteresis effect. Consequently relatively high levels of CO_2 are needed in order to initiate a deglaciation (~1000 ppm; Pollard and DeConto 2005). However, since the inception of the Antarctic ice sheet at the Eocene-Oligocene transition (EOT; 34 Ma), increases and decreases in both $\delta^{18}O$ and global ice volume are reconstructed to have taken place throughout the Neogene. These oscillations are often orbitally paced and are frequently associated with the deglaciation of Antarctica, yet they occur in the apparent absence of big changes in atmospheric CO_2. One interval suited to the further investigation of this issue is the middle Miocene climatic optimum (MCO) (~14.8-16.5 Ma), an interval of relative warmth and reduced ice volume compared to today.

Here we present new high-temporal resolution boron isotope data in foraminiferal calcite from ODP Site 761 between 15.5-17 Ma. Our record shows that CO_2 is elevated to maximum levels of 500-600 ppm between 15.5 and 16.5 Ma but that it is also extremely variable – regularly oscillating from ~300 ppm to ~550 ppm on a roughly 100 kyr time scale. The high and variable CO_2 record presented here goes some way to reconcile the discrepancies between proxy data and the output from coupled global climate models that require CO_2 of the order of 460-580 ppm (You *et al*. 2009) to explain the warmth of the middle Miocene. When our CO_2 record is compared with MCO ice volume records, however, it appears most of the ice volume change occurs at the lower most values of CO_2 in our record, suggesting that a threshold for major melting of the East Antarctic ice sheet is not crossed during the MCO and that a dynamic Antarctic ice sheet existed with a relatively modest CO_2 forcing during the Miocene.

REFERENCES

Pollard & DeConto (2005) Global and Planetary Change 45(1-3) 9-21

You *et al*. (2009) Geophysical Research Letters 36, L4702

The Former BP Micropalaeontology Collection

T. Hill[1], S. Stukins[1] & G. Miller[1]

[1]Department of Earth Sciences, The Natural History Museum, Cromwell Road, London, SW7 5BD, UK
*corresponding author: Thomas.Hill@nhm.ac.uk

The Natural History Museum (NHM) curates the former British Petroleum (BP) Micropalaeontology Collection, which contains micropalaeontology samples from over 3,800 wells and several hundred outcrop sequence from over 120 countries and oceans. The collection includes material dating back to explorations undertaken in the late 1950s and was acquired by the NHM in 1992. The museum has since catalogued and databased this unique resource. The collection includes wet and dry residues, calcareous/silicious microfossils, palynological preparations and nannofossil slides that derive from core, sidewall core and cutting samples, in addition to associated material from many outcrop localities. Due to the commercial sensitivity of the collection, initial access to the collection was restricted. However, it is now possible to obtain access to the resource and the potential value of this collection to micropalaeontological research is very high.

An online museum database and Google Earth layer provides micropalaeontologists with the opportunity to undertake rapid evaluations of whether the collection may contain material beneficial to their research. Similarly, considering the vast spatial and temporal variation of the material encountered, combined with the lack of published research associated with the well run and outcrop microfossil assemblages, there are numerous potential opportunities to develop collaborative projects with the museum to utilise this valuable resource to its full potential.

Keywords: biostratigraphy; palynology; foraminifera; ostracoda

Nanostructure investigations of *Emiliania huxleyi* coccolith elements done by transmission electron microscopy techniques

R. Hoffmann[1]*, A.S. Wochnik[2], C. Heinzl[2], S.B. Betzler[2], S. Matich[3], J.R. Young[4], H. Schulz[5], M. Kucera[6], E. Griesshaber[1], C. Scheu[2] and W.W. Schmahl[1]

[1] Department of Earth and Environmental Sciences, LMU, 80333 Munich, Germany
[2]Department of Chemistry, LMU, 81377 Munich, Germany
[3]Walter-Schottky-Institut, TUM, 85748 Garching, Germany
[4] Earth Sciences, University College London, London WC1E 6BT, United Kingdom
[5]Department for Geosciences, 72074 Tübingen, Germany
[6] MARUM – Center for Marine Environmental Geosciences, University of Bremen, 28359 Bremen, Germany
*corresponding author: Hoffmann.Ramona@lrz.uni-muenchen.de

For material sciences biological calcium carbonate (CaCO3) is becoming more and more interesting, because of its outstanding functionality in comparison to inorganic CaCO3 phases (Mayer and Sarikaya, 2002). We investigated the crystallographic nanostructure of the CaCO3 shell of the coccolithophore species *Emiliania huxleyi*. According to Young *et al*. [2] the coccoliths of this species are composed of two different units with alternating orientation of the crystallographic c-axis: the radial R-unit and the vertical V-unit. In the case of *E. huxleyi* the V-unit will be overgrown by the R-unit during the crystal growth. In this study we used high resolving methods like transmission electron microscopy (TEM) and its analytical techniques, which require very thin samples. Since the skeletal elements of coccoliths are very small cross-section samples were prepared by focused ion beam (FIB) sectioning. Additional plane-view samples were made by dropping the samples onto a TEM grid and etching them afterwards.

Using mainly selected area electron diffraction, bright field and high resolution imaging in the TEM we were able to image and analyze the R- and V-unit of fully grown *E. huxleyi* coccoliths (Fig. 1). For the R-unit the [001] direction points parallel, while the [010] direction points perpendicular to the coccolith plane. The [001] direction of the V-unit is perpendicular, while the [1-10] direction is parallel to the coccolith plane oriented. To investigate the crystallographic structure of the R-unit in detail we applied nano probe experiments with an electron beam diameter of 6 nm, bright field and high resolution imaging. To detect orientation changes within R-unit the diffraction experiments started by tilting the coccolith element to a zone axis. While keeping these angles several diffraction patterns were taken of different areas of the coccolith element. These diffraction patterns were overlain and revealed that the distal- and the proximal element of the R-unit have a relative tilt of 4° ± 1° around the (101) plane normal direction (Fig. 1). Further experiments showed that this misorientation starts already within the middle of the distal shield element. The tilt within and between the shield elements serves to obtain the flat domed character of the coccoliths.

Keywords: Coccolithophores, *Emiliania huxleyi*, Biomineralization, Crystal structure, Electron diffraction, TEM,

REFERENCES

Mayer, G. and Sarikaya, M. (2002) *Experimental Mechanics*, 42, 395-403.

Young J.R., Didymus J.M., Bown P.R., Prins B. and Mann S. (1992) Crystal assembly and phylogenetic evolution in heterococcoliths. *Nature*, 356, 516-518.

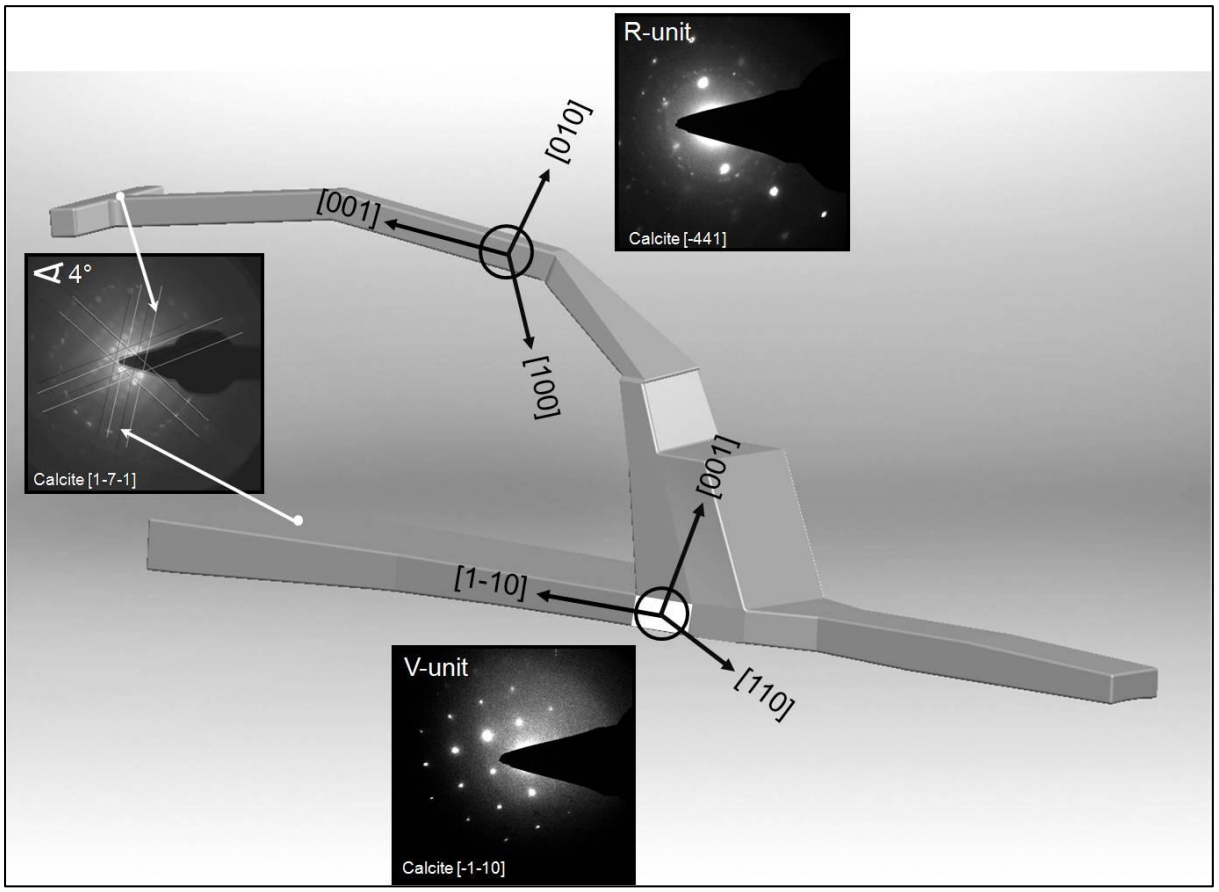


Figure 1: The selected area electron diffraction pattern of the R- and V-unit of *E. huxleyi* are shown and the calculated crystallographic orientations of these crystal units are given in the three dimensional sketch. Furthermore the nano probe diffraction pattern indicating the tilt between the distal- and the proximal shield element is shown.

Caspian climatic cycles for improved petroleum exploration

Tom Hoyle[1]* Suzanne Leroy[1], Keith Richards[2] & Lourdes López-Merino[1]

[1]Institute for the Environment, Brunel University, West London, UK;
[2]KrA Stratigraphic, Deganwy, UK
*corresponding author: tomhoylepalynology@gmail.com

This project aims to elucidate the nature, scale and timing of climate variability in the Caspian region during the Pliocene using palynological and sedimentological approaches. The study will focus on fine grained fluvial-lacustrine deltaic deposits retrieved from well sequences and surface exposures of the Pliocene Productive Series (PPS) in eastern Azerbaijan and the Caspian Sea. Ultimately, as these sediments form the principal hydrocarbon reservoir rocks in the South Caspian basin (Reynolds *et al*, 1998) it is hoped that improved understanding of the reservoir and seal sediments will allow increased efficiency and targeting ability during petroleum exploration.

Due to the onset of rapid subsidence at or around the Miocene-Pliocene transition, the South Caspian basin possesses perhaps the thickest sequence of Neogene-Quaternary sedimentary rocks in the world (Allen *et al*, 2002). Although the mechanisms behind subsidence and sedimentation remain disputed (Allen *et al*, 2002; Green *et al*, 2009; Hinds *et al*, 2004), the thickness of the PPS nonetheless presents the opportunity to carry out high resolution analysis of palaeoclimate and palaeoenvironment proxies throughout the Early Pliocene. We aim to disentangle the effects of external forcing factors such as Milankovitch cyclicities from potential internal drivers such as tectonics, ocean-atmosphere interaction and the changing dynamics of basin infilling over time. The primary method of analysis during the current work entails the identification of pollen, dinoflagellate cysts and other non-pollen palynomorphs (NPP), whose ecological attributes are used to interpret contemporary terrestrial vegetation succession (reconstructing climate) as well as water salinity (reconstructing sea levels). However, issues of taphonomy and preferential preservation must be understood in order that a reliable picture of the local/regional environment can be determined. Likewise, a strong understanding of the fluvial and lacustrine regimes that governed sediment deposition is key in interpreting the palynological signal.

Previously, statistical methods have been used to draw out patterns in palynological data including detailed analysis of local versus regional signals using principal component analysis (López-Merino *et al*, 2012; 2013). The current project will aim to build upon this work by increasing the size of the dataset and also using additional proxies if suitable materials are available (e.g. $\delta^{18}O$ ratios on ostracods or other mollusca, ICP-MS to identify changes in fabric type and heavy mineral analysis to determine sediment source). Such work aims to provide an improved understanding of the origins and distribution of hydrocarbon reservoir and seal sediments, thereby informing the process of petroleum exploration.

Keywords: Caspian; climate; palynology; petroleum

REFERENCES

Allen, M. B., Jones, S., Ismail-Zadeh, A., Simmons, M., & Anderson, L., 2002. Onset of subduction as the cause of rapid Pliocene-Quaternary subsidence in the South Caspian Basin. *Geology*, 30(9), 775-778.

Green, T., Abdullayev, N., Hossack, J., Riley, G., & Roberts, A. M., 2009. Sedimentation and subsidence in the south Caspian Basin, Azerbaijan. *Geological Society of London, Special Publications*, 312(1), 241-260.

Hinds, D. J., Aliyeva, E., Allen, M. B., Davies, C. E., Kroonenberg, S. B., Simmons, M. D., & Vincent, S. J., 2004.

Sedimentation in a discharge dominated fluvial-lacustrine system: the Neogene Productive Series of the South Caspian Basin, Azerbaijan. *Marine and Petroleum Geology*, 21(5), 613-638.

López-Merino, L., Leroy S. A. G., Richards K., Grant S. F., 2012. Environmental reconstruction in the South Caspian Sea Basin using statistical analyses of a palynological dataset from the Neogene Productive Series in Azerbaijan. AAPG Caspian & Black Seas (Baku October 2012). Oral presentation.

López-Merino, L., Leroy S. A. G., Richards, K., Grant S. F., 2013. Environmental reconstruction in the South Caspian Sea Basin using statistical analyses of a palynological dataset from the Neogene Productive Series in Azerbaijan. 14th Congress of Regional Committee on Mediterranean Neogene Stratigraphy, Istanbul, Turkey from 8th to 12th of September, 2013 Oral presentation.

Reynolds, A. D., Simmons, M. D., Bowman, M. B., Henton, J., Brayshaw, A. C., Ali-Zade, A. A.,Guliyev, I. S., Suleyamanova, S. F., Ateava, E. Z., Mamedova, D. N., & Koshkarly, R. O., 1998. Implications of outcrop geology for reservoirs in the Neogene productive series; Apsheron Peninsula, Azerbaijan. *AAPG bulletin*, 82(1), 25-49.

Planktic foraminiferal response to the Latest Danian Event at ODP Site 1210 (Shatsky Rise)

S. Jehle[1]*, A. Bornemann[1], A. Deprez[2], R. P. Speijer[2]

[1]Institut für Geophysik und Geologie, Universität Leipzig, Talstr. 35, 04103 Leipzig, Germany
[2] KU Leuven, Department of Earth and Environmental Sciences, Celestijnenlaan 200 E, 3001 Heverlee, Belgium
*corresponding author: sofie.jehle@uni-leipzig.de

Several transient climatic events severely disturbed the marine ecosystem during the Paleocene, like the Dan-C-2, the Latest Danian Event (LDE), the Early Late Paleocene Event (ELPE) and, most intensely investigated, the Paleocene-Eocene Thermal Maximum (PETM). So far the LDE (or Top Chron 27n Event) has rarely been studied in deep-sea sites and with respect to planktic foraminifera faunas. The LDE has been identified at Zumaia/Spain, Bjala/Bulgaria, Egypt, Shatsky Rise and Walvis Ridge (e.g. Bornemann *et al*., 2009; Westerhold *et a*l., 2011). In the deep-sea the event is characterized by usually two major peaks in Fe concentrations as is evident from XRF core scanning, parallel peaks in magnetic susceptibility, and by a prominent (~1‰) negative carbon isotope excursion (CIE) in benthic foraminifera. Benthic foraminiferal oxygen isotope data of Westerhold *et al*. (2011) from nearby ODP Site 1209 suggest a bottom-water temperature rise of 2°C accompanying the negative CIE. Thus, the LDE has been considered to be a further Paleocene "hyperthermal" that possibly occurred with a reorganisation of the marine ecosystem and ocean acidification.

ODP Sites 1209 and 1210 at Shatsky Rise cover most of the Paleocene. Here we present data of the biotic response (planktic foraminifera assemblages), carbonate dissolution and C, O stable isotope signals of the surface and subsurface water taxa covering about 800 ky around the LDE.

Trends of both O and C stable isotopes of planktic foraminifera show negative shifts at the onset of the LDE. A 0.6‰ decrease in $\delta^{18}O$ lasting for ~100 ky suggests a temperature rise of 2 to 3.5°C. In general the planktic isotope data display some scattering and are noisier than the benthic values, we tentatively infer that the amplitude in both C and O isotope data is about 0.2‰ larger than previously published benthic data (Westerhold *et al*., 2011). Signals in surface and subsurface dwelling foraminifera differ in strength, and $\delta^{13}C$ changes are faster and show a slightly stronger reaction than $\delta^{18}O$ on the event. Dissolution according to planktic foraminiferal fragmentation, P/B-ratios and coarse fraction can be considered to be minor during the LDE, but moderate dissolution has been observed about 300 ky before and 350 ky after the main event peak. Planktic foraminiferal faunas show distinct changes during the onset of the LDE, especially species of Praemurica (uncinata, praecursoria, inconstans), which disappear shortly before, whereas Igorina albeari jumps from 'few' to 'abundant' within the first LDE peak. Morozovella angulata has a slow but constant rise, while M. praeangulata shows the opposite pattern.

Keywords: Paleocene; Latest Danian Event; Shatsky Rise; planktic foraminifera; stable isotopes

REFERENCES

Bornemann, A., Schulte, P., Sprong, J., Steurbaut, E., Youssef, M. & Speijer, R. P. 2009. Latest Danian carbon isotope anomaly and associated environmental change in the southern Tethys (Nile Basin, Egypt). *Journal of the Geological Society*, 166, 1135-1142.

Westerhold, T., Röhl, U., Donner, B., Mccarren, H. K. & Zachos, J. C. 2011. A complete high-resolution Paleocene benthic stable isotope record for the central Pacific (ODP Site 1209). *Paleoceanography*, 26, doi: 10.1029/2010PA002092.

A global overview of planktonic foraminiferal seasonality

Lukas Jonkers[1]* and Caroline Cleroux[2]

[1]School of Earth & Ocean Sciences, Cardiff University, Cardiff, UK;
[2]Royal Netherlands Institute for Sea Research, Den Burg, the Netherlands.
*corresponding author: jonkersl@Cardiff.ac.uk

Planktonic foraminifera are perhaps the most widely used proxy carriers in paleoceanography. The flux of foraminiferal shells to the seafloor varies however on a intra-annual basis, potentially leading to a seasonal bias in the proxy records. This bias, and more importantly, transient changes in seasonality, are often ignored in the interpretation of proxy records. Yet, seasonality may account for an important part of the variability in paleoclimate records and may explain differences between proxies (for instance between foraminiferal Mg/Ca vs. UK'37). Taking the effect of seasonality into account is however hampered by our limited knowledge about what drives seasonality.

To address this issue we have compiled an overview of shell flux seasonality from sediment traps. The database contains 38 globally distributed time series of shell fluxes of at least one year in duration and covers >20 species. We have used this to map shell flux seasonality and its effect on the proxy signal preserved in each species.

Despite the considerable inter-annual variability in the fluxes, many species show, to a first order, a latitudinal pattern in seasonality, confirming that temperature is an important factor in controlling shell flux variability. However, also in the absence of temperature variability, species have distinct seasonality and clear inter-basin differences and small-scale variability in flux timing is observed. All pointing to other, perhaps location specific, factors influencing seasonality.

Flux-weighted temperature offsets from annual mean sea surface temperature for the different species range from ~2° C for tropical surface dwellers such as *G. ruber* and *G. sacculifer* to almost 5° C in temperate species. Clearly, changes in the seasonality of flux can significantly increase or dampen the amplitude of variability in paleoclimate records.

Future steps will include comparison of this new overview with output from ecophysiological models of foraminiferal growth in order to evaluate and improve such models and hence our ability to account for past seasonality shifts in the interpretation of foraminiferal proxy records. The relevance thereof is clearly illustrated by the current overview and as such it provides crucial background information for paleoceanographers and aid proxy calibrations.

Keywords: Planktonic foraminifera; seasonality; flux; sediment trap

A new Pliocene agglutinated benthic foraminifera with a perforated wall structure: implication for deep water oxygenation in the southern Bering Sea

Michael A. Kaminski[1*], Sev Kender[2,3,] and A. Umran Dogan[1]

[1]King Fahd University of Petroleum & Minerals, Earth Sciences Department, PO Box 701, Dhahran, 21361, Saudi Arabia.
[2]Department of Geology, University of Leicester, Leicester, LE1 7RH, UK.
[3]British Geological Survey, Environmental Sciences Centre, Keyworth, Nottingham NG12 5GG, UK.
*corresponding author: kaminski@kfupm.edu.sa

The Bering Sea is the third largest marginal sea in the world. It has particularly low oxygen levels at depth, due to its highly-productivity surface waters and aged deep-water sourced from the deep Pacific, and shallow marine connections with the Arctic Ocean (Expedition 323 Scientists, 2011, IODP Proceedings). IODP Expedition 323 drilled two sites on Bowers Ridge in the southwestern part of the Bering Sea, an extinct arc system that extends 300 km north from the Aleutian Islands. Drilling at Site U1341 recovered nearly 600 m of organic-rich diatomaceous sediment with laminated intervals, and contains a relatively complete palaeoceanographic record back to the Pliocene. The site is located just below the modern Oxygen Minimum Zone (OMZ), which causes the formation of laminated sediments in parts of the section. Fluctuations in the intensity or depth of the OMZ on a variety of timescales should have an impact on the benthic foraminifera at this site in addition to sediment properties. The diatomaceous, largely non-calcareous claystones, recovered from the Pliocene interval of Hole U1341B, have been analysed in this study. They contain a remarkable benthic foraminiferal assemblage consisting exclusively of agglutinated foraminifera (Kaminski *et al*. 2013).

One of the most abundant species in this assemblage is a small enigmatic species of *Karreriella* that has a perforate wall structure. In the case of *Karreriella* sp., unusually the canaliculae are open at the test surface. This is interpreted as a primary feature, as the pores are only present on the lower half of the chambers of the last whorl, and the test surface does not appear to be damaged by abrasion or dissolution. Although open canaliculae have been observed previously in the genus *Clavulina* (Coleman, 1980), this *Karreriella* sp. presents perhaps the clearest example of such a feature that has ever been described in an agglutinated foraminifera.

Such a feature in an agglutinated species recalls the perforate wall structure of a calcareous benthic foraminifer such as in the bolivinids (which are abundant in the Pleistocene section of Site U1341, where there is better calcareous preservation), and is likely to be an adaptation for survival in severely hypoxic conditions present in the deep Bering Sea as far back as the Pliocene.

REFERENCES

Coleman, A.R. 1980. Test structure and function of the agglutinated foraminifera Clavulina. *Journal of Foraminiferal Research*, 10, 143-152.

Kaminski, M.A., Kender, S., Ciurej, A., Balc, R., Setoyama, E. 2013. Pliocene agglutinated benthic foraminifera from Site U1341 in the Bering Sea (IODP Expedition 323). *Geological Quarterly*, 57 (2) 335-342.

Late Miocene to early Pliocene surface processes in the Eastern Equatorial Pacific: 20-kyrs resolution planktic δ18O and δ13C records from Site U1338

G.P. Lee[1]*, A.J. Drury[1], C.M. John[1]

[1]Department of Earth Science and Engineering, Imperial College London, London, UK
*corresponding author: geoff.bluestack@tiscali.co.uk

Globally, late Miocene (11.61 - 5.33 Ma) to early Pliocene (5.33 Ma – 3.60 Ma) climate records indicate relative long-term stability, but regional signals are less clear. For example, the extent to which Equatorial Pacific climate may have been influenced by changes in boundary conditions such as the closure of the Central American Seaway (13 – 1.9 Ma) remains unresolved. We used carbon and oxygen isotope ratios from planktic foraminiferal calcite to investigate regional palaeoceanographic conditions in the Eastern Equatorial Pacific (EEP) (IODP Site U1338), and here consider the implications for globally significant systems such as the El Niño Southern Oscillation.

We measured $\delta^{13}C_{PF}$ and $\delta^{18}O_{PF}$ from 250-355 µm tests of the mixed-layer planktic foraminifer *Globigerinoides sacculifer* on a Kiel IV/Thermo MAT 253 combination at Imperial College London (reacted with 105% orthophosphoric acid at 70 °C with analytical error better than 0.11‰). Measurements were adjusted to the Vienna Peedee Belemnite scale using NBS-19 and in-house Cararra marble standards. An astronomically-based timescale was provided by correlating coeval benthic foraminiferal $\delta^{13}C_{BF}$ and $\delta^{18}O_{BF}$ between Site U1338 and ODP Site 982 (Hodell *et al*., 2001).

Our record spans 8.0 to 4.4 Ma at 15 – 20 kyr resolution. The long-term $\delta^{13}C_{PF}$ trend is characterised by a negative excursion of ~ 0.41‰, but with considerable short-term variations averaging ~ 0.60‰. A large ~ 0.90‰ negative shift between 7.68 and 6.62 Ma likely represents the late Miocene Carbon Isotope Shift. $\delta^{18}O_{PF}$ shows an overall long-term negative trend of ~ 0.42‰ with superimposed short-term fluctuations of ~ 0.50‰, but shows a positive excursion between ~ 6.9 – 6.2 Ma. The long-term trends of both records generally agree well with published planktic isotope records. Preliminary comparison with coeval benthic records at Site U1338 indicates strong covariance, especially between $\delta^{13}C_{PF}$ and $\delta^{13}C_{BF}$.

Published Uk'37 reconstructions indicate stable but cooling sea surface temperatures close to 27 °C (Rousselle *et al*., 2013). Compared to coeval isotopic signatures at ODP Site 806 in the Western Pacific (Nathan and Leckie, 2009), U1338 shows more isotopic variation with generally more positive $\delta^{18}O_{PF}$. This suggests more La Niña-like conditions in the Equatorial Pacific (cf. Nathan and Leckie, 2009). The positive δ^{18}OPF excursion suggests cooling of the EEP and supports the suggestion (Rousselle *et al*., 2013) that the EEP became progressively isolated as the Central American and Indonesian Seaways closed. The strong covariance of $\delta^{13}C_{PF}$ and $\delta^{13}C_{BF}$ at U1338 indicates widespread oceanic reservoir δ^{13}C homogeneity throughout the study period.

Keywords: Foraminifera; stable isotope; Miocene; Pliocene; Equatorial Pacific

REFERENCES

Hodell, D.A., Curtis, J.H., Sierro, F.J., Raymo, M.E., (2001), Correlation of late Miocene to early Pliocene sequences between the Mediterranean and North Atlantic, *Paleoceanography*,16(2), 164-178.

Nathan, S.A., Leckie, R.M., (2009). Early history of the Western Pacific Warm Pool during the middle to late Miocene (~ 13.2–5.8 Ma): role of sea-level change and implications for equatorial circulation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 274, 140–159.

Rousselle, G., Beltran, C., Sicre, M-A., Raffi, I., De Rafélis, M., (2013), Changes in sea-surface conditions in the Equatorial Pacific during the middle Miocene–Pliocene as inferred from coccolith geochemistry, *Earth and Planetary Science Letters*, 361, 412-421.

Understanding nano-crystal assembly in Rhabdophaera clavigera coccoliths using advanced electron microscopy techniques

R. van de Locht[1]* T. Slater[2], A. Verch[1], J. Young[3], S. Haigh[2] & R. Kröger[1]

[1]Department of Physics, University of York, UK
[2]School of Materials, University of Manchester, UK
[3]Department of Earth Sciences, University College London, UK.
*corresponding author: rvdl500@york.ac.uk

Coccolithophores are a type of unicellular phytoplankton. They produce small calcite plates or disks called coccoliths, which are combined to form spherical composites exoskeletons called coccospheres. The coccoliths have remarkably complex nanocrystalline morphologies, impossible to reproduce in synthetic calcium carbonate systems. This strongly suggests that the organism exhibits precise control over the nucleation and growth of the calcite crystals, which motivates a detailed study of the microstructure with the aim to unveil fundamental aspects of nanocrystal formation and assembly in biological systems.

The coccolith ultrastructures of the most common coccolithophore species have been well described primarily based on SEM data. The coccolith rims are characteristically formed of two cycles of interlocking crystal units, one with sub-vertical c-axes, termed V-units, and the other with sub-radial c-axes, R-units, see Young *et al*. (1999). However, central area structures of coccoliths may show rather different morphologies. *Rhabdosphaera clavigera* is a dramatic example of this, exhibiting a several micron long five-fold symmetric spine with a diameter of approximately 0.5 µm, with crystals arranged radially along the longitudinal axis, protruding from the almost flat disks forming the sphere structure.

By a combination of electron microscopy techniques we have reconstructed the structure and the crystallographic orientation of the tip of the spine and its separate crystalline units. The studies reveal that the stem of the spine consists of [104] calcite rhombohedra single crystalline nanoplatelets, each about 1 µm in length and 250 nm in width, arranged in five separate spiral 'staircases' with a 12-14° angle between individual steps. The spine tip shows 15 structural elements: 5 large 'panels' protruding outwards along the lateral plane and 5 leaf shaped smaller units, with an angle of approximately 72° between corresponding elements. The outer tip consists of 5 long platelets protruding along the length of the spine axis. By combining the TEM diffraction data with the HAADF-STEM tomography results we could obtain a detailed image of the nanocrystal arrangement.

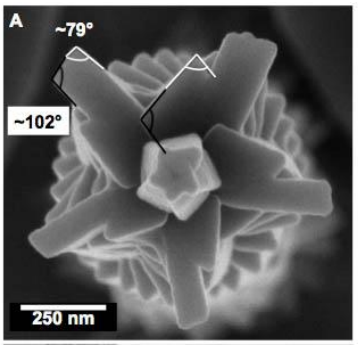


Figure 1:
Apical view of a *Rhabdosphaera* spine

Keywords: coccoliths; calcite; transmission electron microscopy (TEM); scanning transmission electron microscopy (STEM) tomography; crystallography; biomineralisation.

REFERENCES

Young, J.R., Davis, S.A., Bown, P.R., & Mann, S. 1999. Coccolith ultrastructure and biomineralisation. *Journal of Structural Biology*, 126: 195-215.

Sequence stratigraphic application of pollen and spores in deep-water marine hydrocarbon exploration: examples from the late Middle Miocene of the Pearl River Mouth Basin, South China Sea, People's Republic of China

Stephen Lowe[1]*

[1]Integrated Subsurface Description & Modelling Team, BP Reservoir Development & Technology, International Centre for Business & Technology, Sunbury-on-Thames, Middlesex, UK, TW16 7LN
*corresponding author: stephen.lowe@uk.bp.com

Stratigraphic interpretation of land derived palynomorphs in marine palaeo- environments is often a complex and challenging subject. Because of their allochtonous nature, the vertical and horizontal distribution of such palynomorphs in marine sediments reflect sedimentological, taphonomic and diagenetic controls which can variably affect their utility for age dating, facies analysis and correlation. However, the integration of fully quantitative palynology data with well data and seismic dip lines from shelf, slope and deep-water settings can significantly enhance sequence stratigraphic interpretation, correlation and prediction of deep-water hydrocarbon reservoir distribution. An example is presented from the late Middle Miocene (13.8-11.8 Ma) of the Pearl River Mouth Basin, offshore South China Sea, where detailed quantitative palynological analyses of 38 wells reveal highly diagnostic sequence stratigraphic trends in land derived palynomorph distribution. In particular, highly distinctive influxes of the fossil freshwater fern spore *Magnastriatites howardi*, (modern affinity *Ceratopteris*) and fossil mangrove pollen *Florschuetzia levipoli*, (modern affinity *Sonneratia caseolaris*) are shown to be key palynofacies indicators of direct utility to sequence stratigraphic interpretation. The stratigraphic signatures of these taxa provide direct evidence for major basin-wide shifts in facies distribution, precise recognition of key stratal surfaces and palynological characterisation of highstand and transgressive systems tracts. Recent offshore hydrocarbon exploration along the northern margin of the South China Sea has shifted from the shelf to deep-water fan systems with some moderate success. Whilst exploration of these deep-water targets is still at an early phase, the fully integrated palyno-stratigraphic models of the shelf wells provide valuable predictive potential for locating lowstand fan systems in the deep-water South China Sea.

Keywords: Sequence stratigraphy; pollen and spores; hydrocarbon exploration; late Middle Miocene; Pearl River Mouth Basin; South China Sea; People's Republic of China

Upper Valanginian-Hauterivian ammonites and foraminiferal assemblages in Boulahouajeb section (Lansarin Chain, Northeast Tunisia)

S. Melliti[1]*, N. Ben Haj Ali[1], L. Memmi[2], M. S. Arfaoui[1] & F. Zargouni[1]

[1]Université Tunis-El Manar, faculté des sciences de Tunis, département de géologie, Campus universitaire, 2092 Tunis, Tunisia
[2]20, Avenue du 2 Mars 1934- 2025, Salammbô, Tunisie
*corresponding author: sarramelliti@gmail.com

Lithostratigraphical and micropaleontological studies of the Upper Valanginian-Hauterivian successions exposed in the Lansarine Chain, northeast Tunisia, resulted in the establishment of a new biostratigraphical division in the Boulahouajeb section.

As a whole, more than 200 samples were taken with a high-resolution sampling strategy. A rich assemblage of foraminifera and ammonites helps to constrain the biostratigraphical scheme for this area which is in contact with Triassic series. Thus, we recognize ammonite stratigraphy divided into several subzones.

The Late Valanginian is characterized by several seriate sequences of argillaceous limestones, dark marls with intercalation of gray olistholite deposits. This basal unit is defined by *Olcostephanus nicklesi* subzone, Trindosum zone.

The Hauterivian series are formed of dark marls intercalated by some limestones beds, characteristic of the *Plesiospitidiscus ligatus* zone, which indicate the base of the Late Hauterivian. In the uppermost of this series, occur beige gray nodular limestone benches that form the cornice of Boulahouajeb. This bar attributed to the Late Hauterivian, is marked by the *Pseudothurmannia. angulicostata* Zone (named *P.ohmi*), which can be divided into three subzones characterized by three successive species of the genus *Pseudothurmannia*: *Ps. ohmi*, *Ps. catulloi* and *Ps. picteti*.

The foraminiferal succession is divided into three associations based on the first and last occurrences of characteristic benthic foraminifera: 1) A Late Valanginian is characterized by *Lenticulina roemeri* and *lenticulina ouachensis ouachensis*, associated with *Dorothia lilliformis*, *Lenticulina nodosa*, *Ammodiscus cretaceous*, *Lenticulina bartensteni* and *Lenticulina eichenbergi*. 2) A lower Hauterivian assemblage is marked by *Lenticulina ouachensis multicella* associated with *Dentalina gracilis*, *Spirillina neocomiana* and *Frondicularia hastata*. The first occurrences of these taxa are observed near the boundary of the Valanginian and Hauterivian. 3) The Late Hauterivian is characterized by the first occurrence of *Gorbachikella kugleri* (planktonic foraminifera) and an assemblage of *Dorothia Kummi, Dorothia zadlerae* and *Valvulina lusca*. A major faunal event is observed at the top of this series.

The study of this section established a new lithostratigraphical and chronostratigraphical division. The most significant renewal event occurs in the *Plesiospitidiscus Ligatus* Zone with the first appearance of genus of planctonic foraminifera: Gorbachikella represented by *G.kugleri*.

Keywords: Micropaleontology; Stratigraphy; Foraminifera; Ammonites; Upper Valanginian; Hauterivian; Late Cretaceous; Lansarine Chain; Northeastern Tunisia.

Bottom Water changes in the subtropical North Atlantic and the Southern Ocean associated to the Middle Eocene Climatic Optimum

I. Moebius[1]*, O.Friedrich[1], K.M. Edgar[2], H. Scher[3], P.F. Sexton[4]

[1] Institute for Geosciences, Goethe University, Frankfurt, Germany;
[2]School of Earth and Ocean Sciences, Cardiff University, Cardiff, United Kingdom
[3]Department of Earth and Ocean Sciences, University of South Carolina, Columbia, USA
[4]Centre of Earth, Planetary, Space and Astronomical Research, The Open University, Milton Keynes, United Kingdom
*corresponding author: moebius@em.uni-frankfurt.de

The Middle Eocene Climatic Optimum (MECO) is a ~650 kyr interval of pronounced global warming from which the climate system recovered in less than 50 kyr. Despite the valuable insights that the deep-sea sedimentary record could provide on the benthic ecosystem response to this protracted global warming event, and the mechanisms responsible for its relatively rapid recovery, we have little understanding of either. Here we present new insights on bottom water characteristics from ODP Sites 1051 (subtropical North Atlantic) and 738 (Southern Ocean), spanning the MECO and post-MECO interval (41.1 to 39.5 Ma).

At ODP Site 1051 we used benthic foraminiferal assemblages and benthic foraminifera accumulation rates. We find little change in the species composition, but we identify two transient intervals of Benthic Foraminiferal Accumulation Rates increasing by one order of magnitude associated with peak warming: High Productivity Intervals HPI-1 (40.07 – 39.98 Ma) and HPI-2 (39.70 – 39.62 Ma). We correlate these HPIs to intervals of increased organic carbon burial found in the Tethys and suggest that they represent periods of strengthened productivity in the subtropical North Atlantic and the Tethys. At ODP Site 738 we used benthic foraminiferal assemblages in combination with Cerium-Anomaly data. Contrary to Site 1051, we notice a turnover of the benthic foraminiferal communities during the MECO (40.60 and 39.95 Ma) towards an assemblage dominated by infaunal taxa indicative of eutrophication. Additionally, we observe a drop in benthic foraminifera during the peak warming (40.10 – 39.97 Ma), synchronous to a low Cerium-Anomaly and small excursion in εNd values. This indicates a decrease in bottom water oxygenation, potentially caused by the transient influence of an older, oxygen-depleted water mass between.

Overall, this suggests that the extent and rate of environmental change in bottom waters vary greatly in different ocean basins and that the processes influencing bottom waters are subject to big latitudinal differences.

Keywords: Middle Eocene Climatic Optimum; Paleoecology; Benthic Foraminifera Assemblages; Paleooxygenation; Paleoproductivity; Cerium

The Eocene/Oligocene transition in the North Atlantic: Calcareous nannoplankton assemblage shifts

Cherry Newsam[1]*, Paul Bown[1] and IODP Expedition 342 Scientists

[1]Department of Earth Sciences, University College London, London, UK
*corresponding author: cherry.newsam.11@ucl.ac.uk

The Paleogene greenhouse/icehouse transition was a profound interval of long term climatic change and was accompanied by significant biotic change, and in particular, turnover and diversity loss in the calcareous nannoplankton. The middle Eocene through to the early Oligocene experienced climatic deterioration from a greenhouse into an icehouse world culminating in a sharp cooling at the Eocene/Oligocene transition (EOT). A range of global environmental disruption occurred during the EOT including extreme cooling, continental ice sheet growth on Antarctica, sea level fall, >1 km deepening of the calcite compensation depth (CCD), increased ocean alkalinity and marine biotic disturbance, with elevated levels of plankton extinction and turnover, such as the extinction of the Hantkenindae family of planktonic foraminifera which marks the Eocene Oligocene boundary. Calcareous nannoplankton appear to have been the dominant oceanic phytoplankton group in the early Paleogene, up until the EOT, but declined in diversity at this time, though we still know little of the structure and timing of this diversity decline through the late Eocene. Our research aims to document nannoplankton diversity and evolution through this time interval and will examine the relationship between plankton evolution and the striking climatic change.

Here we will present calcareous nannofossil data from a stratigraphically expanded EOT succession, IODP Site U1411, that yields exceptionally well preserved calcareous microfossils. The section was recovered in the North Atlantic Ocean during IODP Expedition 342 (June-July 2012). Simple abundance counts highlight species first and last local occurrences and acmes as well as major shifts in abundance patterns across the EOT transition in high resolution. The demise of warm water oligotrophs (*Coccolithus formosus*, *Reticulofenestra reticulata*, *Umbilicosphaera bramlettei* and *Discoaster* spp) and the increase of species which are considered to have a cold water eutrophic preference (*Reticulofenestra daviesii*, *Isthmolithus recurvus*, *Clausicoccus subdistichus* and *Cyclicargolithus floridanus*) clearly indicate the paleoclimatic/paleoceanographic conditions shifting towards a cooler, more eutrophic environment. Determining the precise timing of these events allows us to examine the relationship between plankton evolution and the strongly shifting paleoclimatic/paleoceanographic conditions in the North Atlantic and more widely at this time.

Coccolithophore calcification at the Paleocene Eocene Thermal Maximum

S.A. O'Dea[1]*, S.J. Gibbs[1], P.R. Bown[2], J.R.Young[2], C. Newsam[1,2], A.J. Poulton[3], P.A. Wilson[1]

[1]Ocean and Earth Science, University of Southampton, National Oceanography Centre, Southampton, Southampton, U.K.
[2]Department of Earth Sciences, University College London, London, U.K.
[3]Ocean Biogeochemistry and Ecosystems, National Oceanography Centre, Southampton, Southampton, U.K.
*corresponding author: Sarah.ODea@noc.soton.ac.uk

As abundant producers of pelagic calcium carbonate in the modern ocean, the sensitivity of coccolithophores to anthropogenic emission of carbon dioxide (CO2) to the atmosphere is of relevance for global biogeochemical cycles and marine ecosystems. Here, we test for coccolithophore calcification responses across an interval of global warming and ocean acidification, associated with a carbon isotope excursion (CIE) to lower values, the Paleocene Eocene Thermal Maximum (PETM, ~56 million years ago). We apply morphometric methods to quantify the skeletal thickness of pristine fossil coccoliths, and combine these measurements with whole-cell biometric data to estimate rates of calcification in fossil coccolithophore populations for the first time. Our data reveal a minor, transient reduction in size-normalised thickness of *Coccolithus pelagicus* immediately prior to the CIE, which represents a hypothesised biomineralisation response to surface water acidification. In addition, we observe a significant decrease in calcite production in *Coccolithus* populations during the interval of maximum warmth, which is likely to reflect changes in environmental factors that control growth rate. In contrast, *Toweius pertusus* maintains a consistent rate of calcite production across the PETM. Our results indicate that the factors that influence the taxonomic composition and biogeography of coccolithophore assemblages and their associated growth rates are likely to be the primary control on overall calcification rates of coccolithophore communities in the coming centuries.

Keywords: Coccolithophore calcification rate; Paleocene Eocene Thermal Maximum; *Coccolithus pelagicus*; *Toweius pertusus*.

Evolutionary trends of *Globigerinoides fistulosus*: elaborate elongations of a Plio-Pleistocene planktonic foraminifer

C. R. Poole[1,2]*, B. S. Wade[1,2] and T. Dignes[3]

[1]Department of Earth Sciences, University College London, Gower Street, London, UK. WC1E 6BT
[2]School of Earth and Environment, University of Leeds, Woodhouse Lane, Leeds, UK. LS2 9JT
[3]Chevron Energy Technology Company, 1500 Louisiana, Houston, TX 77002, USA.
*corresponding author: christopher.poole@ucl.ac.uk

Globigerinoides fistulosus is an important biostratigraphic marker species ranging from Pliocene-Pleistocene. Its evolution is typified by the development of ornate elongations (finger-like 'protuberances'), which differentiate the morphospecies from its (extant) ancestor *G. sacculifer* (Parker 1967, Kennett & Srinivasan 1983). Like many Cenozoic planktonic foraminiferal bioevents, the speciation of *G. fistulosus* occurs through gradual morphological change (i.e. 'pseudospeciation'). Delimitation between the morphospecies is therefore arbitrary. Despite its biostratigraphic utility, the speciation and extinction timings of *G. fistulosus* remain poorly constrained (e.g. Wade *et al*. 2011). Contrasting taxonomic interpretations cause discrepancies in reported first and last occurrences. Such contrasting morphospecies concepts are particularly apparent in the case of *G. fistulosus*. These sources of error are not fully appreciated, but compromise the confidence in bioevent ages and calibration to the geomagnetic polarity timescale.

Interestingly, *G. fistulosus* also appears to show a 'regressive' trend of extinction, by gradual morphological change to *G. sacculifer* forms ('pseudoextinction'; Chaisson & Pearson 1997). Are these perceived anagenetic trends truly representing evolutionary change, or simply a change in mean form (e.g. Kucera & Malmgren 1998), which may be related to varying ecological preferences or even ontogeny?

Morphometric analyses of specimens from Ocean Drilling Program Site 1115 (western Woodlark Basin, Papua New Guinea) are used to assess the morphological evolution of *G. fistulosus* from *G. sacculifer*. Initial qualitative results clearly highlight the extreme morphological plasticity of the *G. sacculifer-G. fistulosus* transition. Most forms appear to arise from *G. sacculifer* through flattening of the final chamber(s) and development of protuberances, although there is significant morphological variation. Some forms, however, exhibit developed protuberances but no chamber flattening. These specimens are analogous to *G. quadrilobatus* (aside from the protuberance development) and differ from the supposed ancestral origin (from *G. sacculifer*). This is perhaps not altogether unexpected, in light of recent evidence suggesting that *G. quadrilobatus* and *G. sacculifer* are in fact genetically the same species (André *et al*. 2013). Quantitative morphometrics will assess final chamber variation on a temporal scale to measure morphological evolution. Multiple morphological parameters will be used to define *G. fistulosus* and provide a quantitative (rather than subjective) morphological delimitation from *G. sacculifer*.

Keywords: evolution, morphometrics, morphospecies concept, biostratigraphy

REFERENCES

André, A., Weiner, A., Quillévéré, F., Aurahs, R., Morard, R., Douady, C. J., de Garidel-Thoron, T., Escarguel, G., de Vargas, C. & Kucera, M. 2013. The cryptic and the apparent reversed: lack of genetic differentiation within the morphologically diverse plexus of the planktonic foraminifer *Globigerinoides sacculifer*. *Paleobiology*, 39, 21-39.

Chaisson, W. P. & Pearson, P. N. 1997. Planktonic foraminifer biostratigraphy at Site 925: middle Miocene–Pleistocene. In: Shackleton, N. J., Curry, W. B., Richter, C., Bralower, T. J. *et al*. (Eds) *Proceedings of the Ocean*

Drilling Program, Scientific Results, 154, 3-32.

Kennett, J. P. & Srinivasan, M. S. 1983. *Neogene Planktonic Foraminifera, A Phylogenetic Atlas*. Hutchinson Ross, Stroudsburg, Pennsylvania. 265pp.

Kucera, M. & Malmgren, B. A. 1998. Differences between evolution of mean form and evolution of new morphotypes: an example from Late Cretaceous planktonic foraminifera. *Paleobiology*, 24, 49-63.

Parker, F. L. 1967. Late Tertiary biostratigraphy (planktonic Foraminifera) of tropical Indo-Pacific deep-sea cores. *Bulletin of American Paleontology*, 52, 115-203.

Wade, B. S., Pearson, P. N., Berggren, W. A. & Pälike, H. 2011. Review and revision of Cenozoic tropical planktonic foraminiferal biostratigraphy and calibration to the geomagnetic polarity and astronomical time scale. *Earth-Science Reviews*, 104, 111-142.

Southern High Latitude Vegetation Response to Rapid Climate Change at the Cenozoic Greenhouse to Icehouse Transition

U. Salzmann[*1], M. Pound[1], S. Strother[1], F. Sangiorgi[2], P. Bijl[2], S. Houben[2], J. Pross[3], I. Raine[4] & H. Morgans[4]

[1]Department of Geography, Northumbria University, Newcastle, UK
[2]Department of Earth Sciences, University Utrecht, Utrecht, The Netherlands
[3]Institute of Geosciences, Heidelberg University, Heidelberg, Germany
[4]GNS Science, Lower Hutt, New Zealand
*corresponding author: ulrich.salzmann@northumbria.ac.uk

Declining greenhouse gasses and/or tectonic opening of ocean gateways are discussed as potential causes for the rapid cooling at the Eocene-Oligocene (E/O) transition ca. 33.5 million years ago, promoting the onset of the Antarctic glaciation. We will present preliminary palynological results from Eocene to Oligocene sections of IODP Leg 189 "Tasman Gateway", IODP Leg 318 "Wilkes Land" and sediments outcrops at Cape Foulwind, New Zealand. In order to further understand the vegetation response to global climate change at the E/O transition, we also integrated the new palynological data with global vegetation reconstructions synthesised from literature. Our combined approach will test whether the opening of the Tasmanian Gateway at the E/O transition led to a major reorganisation of ocean currents, during which southeast Australia came under the influence of warmer surface waters, which affected continental climates and vegetation. We will further test whether the crossing of atmospheric CO_2-thresholds and/or plate tectonic changes resulted in a stepwise cooling of New Zealand and Antarctica as the Antarctic Circumpolar Current developed.

Keywords: Eocene, Oligocene, Antarctica, New Zealand, Australia, Tasman Sea, Palynology

Morphometric responses of coccolithophores to Paleogene environmental change

Rosie M. Sheward[1]*, Samantha J. Gibbs[1], Alex J. Poulton[2], Paul A. Wilson[1]

[1]Ocean and Earth Science, National Oceanography Centre, Southampton, University of Southampton, Southampton, SO14 3ZH
[2]Ocean Biogeochemistry and Ecosystems, National Oceanography Centre, Waterfront Campus, Southampton, SO14 3ZH
*corresponding author: rosie.sheward@noc.soton.ac.uk

CO2-driven environmental changes are expected to impact the calcification ability, physiology and ecology of calcifying organisms such as the phytoplankton group coccolithophores. A potential for adaptive evolution to lower pH conditions in coccolithophores has been indicated by recent multigenerational culture experiments, yet the sensitivity and evolutionary responses of this important group to greenhouse conditions remains poorly understood. The Paleogene, 65.5 to 33.5 million years ago, was the last interval of sustained greenhouse conditions, with brief extreme global warming events known as hyperthermals interspersed throughout. The cellular level responses of coccolithophores to warming and ocean acidification is ideally recorded in the geological record, with macroevolutionary trends giving insights into the adaption potential of this group to future climate change.

Here, the relationship between cell size, coccosphere morphometrics and physiological processes is applied to exquisitely preserved fossil coccospheres from globally-distributed Paleogene sites to examine cellular-level evolutionary trends. We find statistically significant relationships between coccolith length and coccosphere diameter in all studied Paleogene coccolithophore groups, notably *Toweius* and *Reticulofenestra* groups, which are the ancestors of the modern taxa *Emiliania huxleyi* and *Gephyrocapsa*, and *Coccolithus pelagicus*, which continues to occur in the modern ocean. We also report significant relationships between coccolith number per cell and coccosphere diameter in *Coccolithus*, *Reticulofenestra* and *Cyclicargolithus* groups. The degree of variability in coccolith length and coccosphere size explained by these relationships is nevertheless low, strongly indicating that cell size in coccolithophores is a complex interplay of coccolith length, coccolith thickness and number of coccoliths per cell.

Species-specific shifts in coccosphere geometry through time indicate physiological responses to temperature, nutrient and light availability during the greenhouse-icehouse transition. The environmental controls on these morphometric characteristics remain poorly understood in living species, although coccolith number per cell has been recently linked to growth phase. The ability to identify specific environmental characteristics in coccosphere geometry will aid our interpretation of cell size shifts through time in relation to Paleogene environmental proxies. Furthermore, this is essential if these relationships are to reconstruct cell size records from the single, disarticulated coccoliths that overwhelmingly dominate the geological record.

Keywords: Paleogene; coccolithophore; cell geometry; greenhouse-icehouse transition

Micro vs. Macro: A quantitative comparison of palynological and plant macrofossil data from a Jurassic plant bed

S. Slater[1*] and C. Wellman[1]

[1]Department of Animal and Plant Sciences, University of Sheffield, Sheffield, UK

*corresponding author: bop11sms@sheffield.ac.uk

Palynomorphs from Middle Jurassic terrestrial deposits of the Ravenscar Group from the Cleveland Basin in northeast Yorkshire, UK are used to reconstruct palaeoenvironmental conditions at this time. Assemblages of abundant, diverse and well preserved palynomorphs have been recovered from numerous horizons throughout the sequence. A five metre section through a plant bed from Hasty Bank, North Yorkshire, UK has been sampled at 10 cm intervals for high resolution analysis of spore/pollen and palynofacies assemblages. The macrofossil palaeobotany of this section was previously assessed in detail (Spicer and Hill, 1979) by analysing quantitative palaeobotanical count data using multivariate plots. Quantitative palynological data is compared with previous palaeobotanical data by assigning spores/pollen to parent plant taxa. This enables integration of dispersed spore and pollen studies with palaeofloristic reconstructions. Correspondence and principal components analysis in conjunction with absolute abundance data shows lithology is the dominant factor controlling spore/pollen assemblages and palynofacies compositions. Palynological assemblages display evidence of larger catchment areas than palaeobotanical macrofossil data. Despite this, palynological data in this section is considered to be more representative of the true palaeoflora due to the preferential preservation of more durable plant taxa such as Equisetum, which artificially inflates relative abundances of many species in macrofossil assemblages.

Keywords: spores; pollen; Jurassic; multivariate plots; Hasty Bank; Ravenscar Group.

High abundances of early Miocene biserial planktic foraminifera: palaeoceanography and evolution

C.W. Smart[1]* & E. Thomas[2,3]

[1]School of Geography, Earth and Environmental Sciences, Plymouth University, Drake Circus, Plymouth, Devon, PL4 8AA, U.K. [2]Department of Geology and Geophysics, P.O. Box 208109, Yale University, New Haven, CT 06520-8109, U.S.A.
[3]Department of Earth and Environmental Sciences, Wesleyan University, Middletown CT 06459, USA
*corresponding author: csmart@plymouth.ac.uk

Small biserial planktic foraminifera were abundant in the early Miocene (~19-17 Ma) in the eastern Atlantic and western Indian Oceans. They were originally assigned to the benthic genus *Bolivina*, but accumulation rates and isotopic composition of the tests show that they were planktic, thus assigned to the genus *Streptochilus* (Smart and Thomas, 2006, 2007). However, the modern species *S. globigerus* is genetically identical to benthic *B. variabilis*, and thus occupies both planktic and benthic domains (tychopelagic) (Darling *et al*., 2009). Such taxa could have evolved into true planktic species in the past, and the early Miocene coeval appearance of several short-lived species in the eastern Atlantic and western Indian Ocean may indicate multiple evolutionary origins of biserial planktic species, as well as an environmental driver of their evolution. Their distribution in the modern ocean is not well known, but they have mainly been observed in variable, highly productive, commonly coastal waters with intermittent upwelling.

At DSDP Site 608 (NE Atlantic Ocean) high abundances of *S. rockallkiddensis* occur at ~19-17 Ma, coeval with abundant sphenoliths in nannofloral assemblages, and high alkenone carbon isotope values, indicating high growth rates of haptophyte algae. Early Miocene high *Streptochilus* abundances may reflect vigorous but intermittent upwelling of nutrient-rich waters, inducing high growth rates of phytoplankton. Low BFARs suggest low export production and high regeneration rates of organic matter in an expanded thermocline. In this food-rich, deep-thermocline niche diatom-feeding benthic species exported from shelf regions may have survived and evolved into true planktic species.

An as yet undescribed biserial species in the biogenic silica-containing upper Oligocene/lowermost Miocene of the South Tasman Rise (ODP Site 1170) was, according to its stable isotope values, also planktic. It had been argued that biserial planktic species were absent in the upper Oligocene, but we show that biserial planktic species occurred throughout the Cenozoic, originating multiple times independently from benthic ancestors, specifically *Bolivina* species. It is unclear what triggered their evolution and specifically the coevolution of three different species in the early Miocene. Possibly changes in the Southern Ocean ecosystems during cooling, specifically in combination with the increase in diatom abundance and size, led to changes in the particle export efficiency from the photic zone and the transfer efficiency to the seafloor. Changes in the Agulhas leakage around South Africa and thus in nutrient export into the oceans around the African continent in the early Miocene may have been a factor.

Keywords: Miocene; *Streptochilus*; palaeoceanography; evolution.

REFERENCES

Darling, K.F., Thomas, E., Kasemann, S.A., Seears, H.A., Smart, C.W. and Wade, C.M., 2009. Surviving mass extinction by bridging the benthic/planktic divide. *Proceedings of the National Academy of Sciences*, 106, 12629-12633.

Smart, C.W. and Thomas, E., 2006. The enigma of early Miocene biserial planktic foraminifera. *Geology*, 34, 1041-1044.

Smart, C.W. and Thomas, E., 2007. Emendation of the genus Streptochilus Brönnimann and Resig 1971 (Foraminifera) and new species from the lower Miocene of the Atlantic and Indian Oceans. *Micropaleontology*, 53, 73-103.

limate change in northern high latitudes over the Eocene-Oligocene boundary; analysing nannofossil biota and climate changes at ODP 647, Labrador Sea.

K.V. Smith[1]*

[1]School of Geography, Earth and Environmental Sciences, The University of Birmingham, Edgbaston, Birmingham, B152TT, United Kingdom
*corresponding author: KVS978@bham.ac.uk

The Ocean Drilling Program Expedition 647A core in this study was drilled in October 1985 on the ODP Leg 105 at a site that is situated between Greenland and Canada 100km off the southern flank of the Gloria Drift (53°20'N, 45°16'W). This ODP Expedition was initially to look at the tectonic history and palaeoceanography of high-latitudes. The nannofossil assemblages of this core have not been investigated in much detail but an approximate biostratigraphy exists. The aims of this study were to reanalyse the assemblage components and the taxonomy over the Eocene-Oligocene boundary (EOB) and provide a good taxonomic overview of the Eocene-Oligocene transition (EOT). This forms part of ongoing research which includes linking assemblage changes over the EOB in the northern high latitudes to the onset of early glaciation in the Arctic through crossover dominance between warm water and cold water taxa.

A total of 569 sub-split samples were provided by the Ocean Drilling Program. This high resolution study used 29 of these samples taken on average at 10cm intervals across the EOB as part of the original Master's thesis. This section is currently being expanded in order to contain more samples in the late Eocene and early Oligocene and provide a more detailed picture. Around 29 different taxa have been identified so far in the study with the dominant taxa being: *Reticulofenestra minuta, Reticulofenestra daviesii, Reticulofenestra lockeri* and *Coccolithus pelagicus*.

Keywords: Eocene; Oligocene; nannofossils; Labrador Sea; Taxonomy

Mg/Ca variability of planktonic foraminifera *Globigerinoides ruber* from a sediment trap off Bermuda

R. Smith[1, 2]*, A. Sadekov[1], S. Misra[1], H. Elderfield[1], M. Conte[3, 4], W. Curry[5]

[1]Department of Earth Sciences, University of Cambridge, Cambridge CB2 3EQ, UK
[2]National Oceanography Centre, University of Southampton, Southampton SO14 3ZH, UK
[3]Bermuda Institute of Ocean Sciences, Ferry Reach, St Georges GE01, Bermuda
[4]Ecosystems Center, MBL, Woods Hole, MA 02543, USA
[5]Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA
*corresponding author: Richard.Smith@noc.soton.ac.uk

Foraminiferal test (shell) Mg/Ca ratios are widely used to estimate ocean palaeotemperature. Test Mg/Ca has been shown to increase exponentially with growth temperature, but a number of issues with the proxy remain unresolved. For example, significant Mg/Ca variability is observed between individual tests which grew at similar temperatures, despite the 'bulk' average Mg/Ca of these tests correlating well with growth temperature (Sadekov *et al*., 2008). In addition, low- and high-Mg bands have been shown to cause considerable Mg/Ca variability within individual tests (Eggins *et al*., 2004).

Surface-dwelling foraminifera *Globigerinoides ruber* (white) were collected over seven two-week periods between 2004-05 by a sediment trap at 3200m depth in the Sargasso Sea. An average of 14 tests per collection period were analysed for Mg/Ca using Laser Ablation ICP-MS. Only final-forming chambers were analysed, so that accurate constraints on growth date could be made, thus enabling comparison with contemporaneous seawater temperature records. Considerable inter-test Mg/Ca variability was observed: the average range of Mg/Ca-estimated growth temperatures among individual tests from the same two-week period was several times greater than the corresponding range of daily average sea surface temperature measurements. Test thickness was found to show no correlation with test Mg/Ca, suggesting that previously reported low- and high-Mg intra-test bands do not contribute noticeably to inter-test variability. Two morphotypes of G. ruber were identified, and in three samples *G. ruber ruber* was estimated to have grown in water 3˚C warmer than *G. ruber pyramidalis*. This supports previous suggestions of a shallower depth habitat for *G. ruber ruber* (Steinke *et al*., 2005).

Keywords: Foraminifera; Mg/Ca; laser ablation

REFERENCES

Eggins, S. M., Sadekov, A., & De Deckker, P. (2004). Modulation and daily banding of Mg/Ca in Orbulina universa tests by symbiont photosynthesis and respiration: a complication for seawater thermometry? *Earth and Planetary Science Letters*, 225(3), 411-419.

Steinke, S., Chiu, H. Y., Yu, P. S., Shen, C. C., Löwemark, L., Mii, H. S., & Chen, M. T. (2005). Mg/Ca ratios of two Globigerinoides ruber (white) morphotypes: Implications for reconstructing past tropical/subtropical surface water conditions. *Geochemistry Geophysics Geosystems*, 6(11), Q11005.

Sadekov, A., Eggins, S. M., De Deckker, P., & Kroon, D. (2008). Uncertainties in seawater thermometry deriving from intratest and intertest Mg/Ca variability in *Globigerinoides ruber. Paleoceanography*, 23(1), PA1215.

Sensitivity Of Extra-Cellular Calcifying Coccolithophores To Ocean Acidification: Exceptionally Preserved Nannofossil Records From The US East Coast Margin

J.F. Spray[1]*and S.J. Gibbs[1]

[1]National Oceanography Centre, University of Southampton, Southampton SO14 3ZH, UK
*corresponding author: jfs1g12@soton.ac.uk

The current trend in anthropogenic CO2 release is leading to the acidification of the oceans and is significantly altering carbonate chemistry, with potential negative effects for calcifying organisms. Coccolithophores are a key calcifier in modern and cenozoic oceans and their response to ocean acidification in the fossil record may lead to a better understanding of how they will cope in the current climate, however evidence of any negative impacts across past acidification events is contentious (Gibbs *et al*., 2006). Here we present abundance data from across the Paleocene Eocene Thermal Maximum, a well-known analogue for the current scenario, for a sub-group of calcifying coccolithophores the holococcoliths and braarudosphearids. We have targeted these coccolithophores as they may be particularly sensitive to acidification because of their hypothesised (semi-)extracellular mode of calcification (Tyrell & Young, 2009). Data were collected along a transect of cores from the northeast US, to allow for separation of local and spatially extensive environmental influences. Our results suggest that we cannot rule out acidification as being a control on holococcolith abundance across the PETM in this region, but that the extent of OA-control appears to have been outweighed by local factors such as nutrient input or oceanographic changes.

Keywords: PETM; acidification; coccolithophores.

REFERENCES

Gibbs, S.J., Bralower, T.J., Bown, P.R., Zachos, J.C. & Bybell, L.M. (2006). Shelf and open ocean calcareous phytoplankton assemblages across the Paleocene-Eocene Thermal Maximum: Implications for global productivity gradients. *Geology*, 34 (4), 233-236.

Tyrrell, T. & Young, J.R. (2009). Coccolithophores. In *Encyclopaedia of Ocean Sciences*, 2nd edition (Steele, J. H., Turekian, K. K. & Thorpe, S. A., eds.). pp. 3568-3576. Academic Press, San Diego.

Novel monothalamous benthic Foraminifera associated with planktonic shells and mineral grains from the Porcupine Abyssal Plain

P.V. Stefanoudis[1]* & A. J. Gooday[1]

[1]National Oceanography Centre, Southampton, Empress Dock, European Way, Southampton SO14 3ZH, UK

*corresponding author: p.v.stefanoudis@soton.ac.uk

Monothalamous (single-chambered) Foraminifera have traditionally been neglected in deep-sea benthic studies due to their obscure morphology and lack of distinctive taxonomical features, despite the fact they constitute an important component of the benthic fauna at abyssal depths. The purpose of this study is to address the importance of agglutinated monothalamids. We focus on those that live attached to or are lodged between planktonic or mineral grain shells, with the aim of providing an informal morphology-based classification framework. Sediment samples were collected using a multiple corer at two sites on the Porcupine Abyssal Plain. Site A (4818 m) and site B (4330 m) represent topographically low (flat seabed) and high (seamount peaks) areas, respectively. Site B has a higher percentage of coarser sediment. Foraminifera were picked from the >300 μm and 150-300 μm size fractions of the 0-1 cm sediment layer.

Sieve residue were stained with Rose Bengal and sorted for Foraminifera in water undera binocular microscope. The monothalamids studied constituted 42% and 40% of the total 'live' (stained) assemblage from the >300 μm and the 150-300 μm size fraction respectively. The corresponding percentages for the dead assemblage were 75% and 30%. A small fraction (<5 %) of specimens, usually containing brown stercomata, could not reliably be identified as live and therefore they were termed as '?live'. In total, 16 morphotypes were identified from the two sites. Of those, 8 were considered to represent species, while the rest were collections of morphologically similar organisms. The two most abundant species were: i) chambers between planktonic shells with one or more flimsy tubes (Figure 1a), and ii) simple domes attached to large planktonic Foraminifera shells with a much smaller planktonic shell sitting on top of the dome, like a hat (Figure 1b).

Monothalamid tests made from, or including mineral grains were unique to the high site (Figure 1c), reflecting the coarser sediment at that site. More work is necessary in order to refine these morphotypes and to recognize morphologically coherent types that can be regarded as distinct species. The current study will hopefully set the basis for future work with this virtually unknown component of abyssal North Atlantic foraminiferal faunas.

Keywords: Foraminifera; monothalamids; deep-sea benthos; diversity; morphotypes

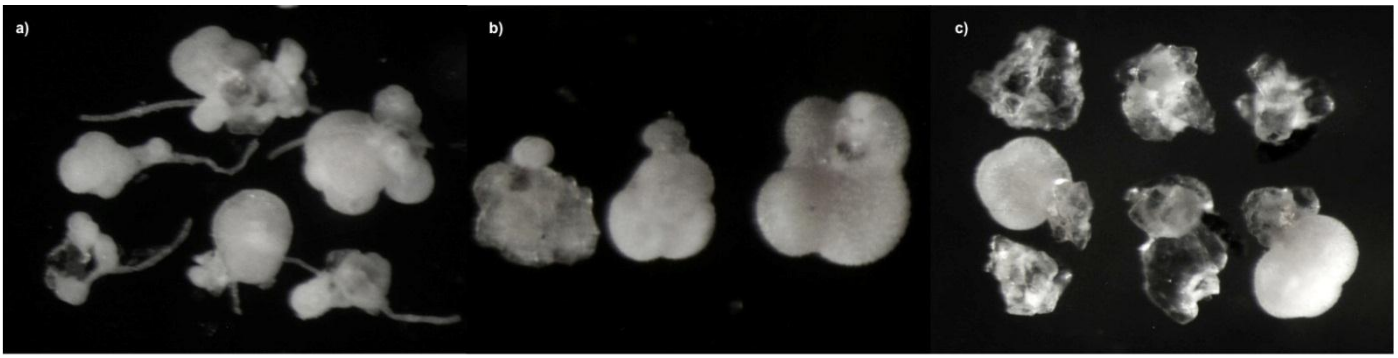


Figure 1. Light microscope images of monothalamids: a) chambers between planktonic shells with one or more flimsy tubes, b) simple domes attached to large planktonic Foraminifera shells with a much smaller planktonic shell sitting on top of the dome, like a hat and c) single-chambered tests made from, or including mineral grains.

Microfossil adventures in the Iron Age

C.P. Stocker[1*], M. Williams[2], I.P. Wilkinson[3], J. Taylor[4], I. Whitbread[5]

[1,2]Department of Geology, University of Leicester, Leicester, United Kingdom;
[3]British Geological Survey, Keyworth, Nottingham, United Kingdom.
[4,5]School of Archaeological Studies, University of Leicester, University Road, Leicester, United Kingdom
*corresponding author: cs300@student.le.ac.uk

Burrough Hill in east Leicestershire is one of the finest examples of a single-walled Iron Age Hill Fort in the East Midlands. Archaeological studies show continuous occupation from the late Bronze Age through the Iron Age and into the Roman period. Excavations have yielded a host of pottery artefacts and building materials containing microfossils, which have proved invaluable for discerning the provenance of clay materials used in manufacturing and construction. Here we examine the signature of microfossils recovered from Iron Age pottery at the site, and develop new techniques from experimental clay pot taphonomy to determine possible ceramic manufacturing techniques.

Keywords: archaeology; calcareous microfossils;

The John Williams' Index of Palaeopalynology

S. Stukins[1], T.C.B. Hill[1] & G.Miller[1]

[1]Department of Earth Sciences, The Natural History Museum, Cromwell Road, London, UK
*corresponding author: S.Stukins@nhm.ac.uk

The John Williams Index of Palaeopalynology (JWIP) is a card catalogue stored at the Natural History Museum, London, and is based around a central index of over 23,350 references (as of February 2012). The card catalogue began in 1971 by John Williams who has been the sole contributor to this unique resource since its creation. The references included within the catalogue are a thorough collection of palaeopalynological journal articles, textbooks, selected conference abstract volumes, and MSc and PhD theses etc. available online, that have been reviewed by the author since creation of the catalogue some 40 years ago. The catalogue evolves around a central card index (labelled 'JWIP References'), from which each reference is then cross-referenced into separate card catalogues categorised by palynomorph group (spores/pollen, dinoflagellate cysts and acritarchs, chitonozoans and miscellaneous), taxa (spores/pollen, dinoflagellate cysts, acritarchs and chitonozoans), geological period (26 divisions) and geographical region (17 regions).

Due to this unique format, the card index enables a user to undertake a search based on the specific needs of their research, whether it is the investigation of individual taxa in a taxonomic study, or an evaluation of assemblage data in a specific time or region, for example, allowing the user to find all the relevant references. The number of references obtained during each card index search surpasses generic web searches and/or academic search engines in terms of accuracy and detail. In addition, whilst the entire card index has been compiled by John Williams, each publication is also assiduously checked by John prior to being inputted into the card index. This results in the reliability and consistency encountered in the card index surpassing that of Palynodata, the only known comparable compilation of palynological data.

The card index is still growing, with John Williams adding information to the index of some 1000 additional references each year. The NHM are in the process of evaluating potential avenues to convert this into a digital resource. This presentation will review the resource, its structure and provide examples of its application to existing and potential palynological research.

Keywords: card index; database; marine; terrestrial; Cenozoic; Mesozoic; Palaeozoic.

REFERENCES

Riding, J., Pound, M., Hill, T.C.B., Stukins, S., Feist-Berkhardt, S. (2012) The John Williams Index of Palaeopalynology. Palynology, 36, 2, 224-233.

The preliminary study of calcareous nannofossils assemblages for interpreting EOT boundary of Mossy Grove Core, Mississippi, US

N.Sulaiman[1*], T.D.Jones[2] & I.Boomer[3]

[1] Faculty of Earth Sciences, University Malaysia Kelantan, Malaysia; Department of Earth Sciences, University of Birmingham, UK

[2, 3] Department of Earth Sciences, University of Birmingham, UK

*corresponding author: NXS251@bham.ac.uk

The Mossy Grove core composed of about 550 feet of samples and dominant by a Yazoo Clay Formation. It would be interest to investigate the complete Eocene/Oligocene transition boundary based on its well preservation, assemblages and abundances of calcareous nannofossils. The Eocene/Oligocene transition boundary was significance during the shifting from the warm temperature (Greenhouse) to cold temperature (Icehouse) of the earth. 75 samples were examined under light microscope (x1250) and a quantitative counting approach had been taken to get the relative abundance of nannofossils. From this study, the assemblages were dominated by four species which are *Reticulofenestra dictyoda* (small), *Reticulofenestra minuta*, *Cyclicargolithus floridanus* and *Coccolithus pelagicus*, with additional 65 other species. The complete section of Eocene-Oligocene transition is shown by the presence of bioevent marker species, *Reticulofenestra reticulata*, *Discoaster saipanensis*, *Discoaster barbadensis*, I*smolithus recurvus* and *Coccolithus formosus* which marked NP17 to NP21 zone of Martini, 1971, respectively. Based on the assemblages of cool and warm water taxa, the EOT boundary is most probably present between 150-200 feet, within NP21. The highest occurrence (Top) of *Coccolithus formosus* occurs at 79 feet (top of NP21) and the top of *Discoaster saipanensis* and *Discoaster barbadensis* occurs at 263 feet (top of NP 20). Relatively, the calcareous nannofossils in this study suggest a ~1Ma younger age compared to the age model of planktonic foraminifera (Fluegemen, 2009), although it shows the same general sedimentation rates. Together with all the current assemblages data, we aim to undertake further geochemical studies, to reconstruct EOT event, marine temperatures and coccolithophores productivity.

Keyword: EOT; calcareous nannofossils.

REFERENCES:

Martini, E., 1971, Standard Tertiary and Quaternary calcareous nannoplankton zonation, in Farinacci, A., ed., *Proceedings of the Second International Conference on Planktonic Microfossils* 1970: Rome, Edizioni Tecnoscienza, 2, p. 739–785.

Quantitative Planktonic Foraminifera Micropaleontology on the old and for future IODP legs

M.J. Vautravers[1]*

[1]Godwin Laboratory for paleoclimate Research, Cambridge University, UK
*corresponding author: mv217@cam.ac.uk

From (i) the high resolution study of Quaternary planktonic foraminifera associations to (ii) gaining valuable complementary data for a new long Cenozoic isotopic record to (iii) checking the feasibility of a future IODP leg in challenging environments, e.g. near Antarctica; quantitative micropaleontology keeps providing the Earth scientists with invaluable insights into the operation of the Earth system.

Particularly quantitative studies are relevant in highlighting the potential problems and challenges to be encountered as a result of taphonomic bias or very low microfossils abundances resulting from intense dilution /dissolution or production.

Here, I present:

(i) a quantitative study based on several old Sites covering the whole Cenozoic and for which using the % planktonic foraminifera fragments, the number of whole PF/cc, and values of species richness. Altogether I show the quasi-pervasiveness of $CaCO_3$ dissolution at these "historical ODP & IODP sites" during the last 67 Ma.

(ii) (ii) A quantitative study which gives hopes for a much needed future near West Antarctic IODP drilling expedition resting on the challenging but possible use of the "classic" $\delta^{18}O$ isotopic analysis on extremely rare planktonic foraminifera to be extracted from the samples of drift sediments to be recovered at depth c. 2000m off the Antarctic Peninsula (IODP proposal 732).

Late Campanian (*Radotruncana calcarata* zone) foraminifera communities from the Austrian Alps

E. Wolfgring[1]* and M. Wagreich[1]

[1]Department of Geodynamics and Sedimentology, Universität Wien, Althanstrasse 14, 1090Wien,
*corresponding author: erik.wolfgring@univie.ac.at

The pelagic Postalm section in the Northern Calcareous Alps (Austria) has been subject of intense investigation during the past years. With the construction of a mountain road, an outcrop depicting a complete succession of Santonian to Maastrichtian sediment has become accessible and has in the following undergone detailed stratigraphic investigation allowing chronostratigraphic correlation and the implementation of a cyclostratigraphic model (Wagreich *et al*., 2012).

This study focuses on plankton biostratigraphy of the *Radotruncana (Globotruncanita) calcarata* total range zone.

Over 66 samples from pelagic limestone/marl cycles have been examined for foraminifera aiming at a high resolution assessment of the assemblages present. Combining these results to cyclostratigraphic and geochemical data might provide additional information on the palaeoecology and could lead to an accurate reconstruction of the palaeoenvironment.

Observed long-term as well as sudden changes in foraminifera abundances or assemblage types could be influenced by orbital cyclicity and associated environmental changes and thus offer the possibility to correlate them to the previousely established cyclostratigraphic model.

Qantitative analyses show typical Late Campanian foraminifera communities. The assemblages are dominated by members of the genus *Hedbergella* and small (< 125µm) members of *Heterohelix*, as well as *Globigerinelloides*. *Globotruncanids* observed are represented with less than 20 percent, including the genera *Radotruncana*, *Globotruncana*, *Globotruncanella*, *Globotruncanita* and *Contusotruncana*. Benthic taxa occur in varying numbers, but are present in every sample. A qualitative analysis of the assemblage demonstrates the presence of over 90 different benthic taxa. Despite a comparatively high taxonomic richness in benthic taxa their share of the total community is negligible.

A comparable section is provided in Oberhehenfeld from the Ultrahelvetics. With each the sections representing an outcrop from opposing sides of the Tethyan Oceans basin, qualitative data from Postalm (Northern Calcareous Alps) has been compared to Oberhehenfeld and shows a very similar taxonomic composition. No local stratigraphic events are evident. Differences in the presence of infaunal agglutinating taxa, such as *Bathysiphon* spp., have been observed.

Yet no distinct response to changes in geochemical proxies, such as changes in Sr. isotope values, or ecological factors, could be registered. The two sections from the Austrian Alps examined in this study seem to represent perfectly quiet pelagic environments without any substantial changes evident in foraminifera communities throughout the *R. calcarata* zone.

REFERENCES

Wagreich M., Hohenegger J., Neuhuber S. (2012). Nannofossil biostratigraphy, strontium and carbon isotope stratigraphy, cyclostratigraphy and an astronomically calibrated duration of the Late Campanian *Radotruncana calcarata Zone. Cretaceous Research*, 38: 1-17

Late Jurassic to Early Cretaceous Dinoflagellate Cysts from the Eastern Gulf of Mexico: Facilitating future exploration and development activities in the basin.

Stephanie Wood[1*], Charles Wellman[1] and Iain Prince[2]

[1]Department of Animal and Plant Sciences, University of Sheffield, Sheffield, UK
[2]Shell Exploration and Production, Woodcreek Research Facility, 200 North Dairy Ashford, Houston, Texas, USA
*corresponding author: selw89@gmail.com

The Late Jurassic to Early Cretaceous deposits of the Eastern Gulf of Mexico (EGoM) are one of the world's major hydrocarbon reserves. However, there is a distinct lack of published studies on dinoflagellate cysts from these strata. Instead hydrocarbon companies have relied on published work from Europe, and have attempted to correlate European stratigraphy and dinoflagellate cyst biostratigraphy with that from the EGoM. Such a technique lacks accuracy. This research aims to produce a higher resolution dinoflagellate cyst biostratigraphy from data collected from three wells around the EGoM.

The Gulf of Mexico (GoM) is a structurally complex area in terms of its tectonic setting. During the Late Jurassic carbonate deposits with small interspersed and interbedded shales and red sandstone bodies accumulated in the EGoM. At the same time oceanic crust emerged in the centre of the Gulf of Mexico (GoM) basin, while the Yucatan Block rotated counterclockwise to the south-east of the basin. Marine transgression followed the production of oceanic crust, and as the GoM basin crust cooled and thermally subsided relative sea level rose. Thermal subsidence continued into the Early Cretaceous and a carbonate shelf margin platform prograded. Thermal subsidence of the lithosphere controlled the sedimentation rates and architecture of the GoM basin. The unusual tectonic setting of this locality therefore requires a well age-constrained stratigraphy to be established to link formations and structures further around the EGoM basin.

Preliminary studies demonstrate that rich assemblages of well-preserved palynomorphs occur in these deposits. These are dominated by dinoflagellate cysts but also include subsidiary spores. The samples are being analysed using light and scanning electron microscopy. The dinoflagellate cysts will be systematically described and quantitative data concerning their occurrence/abundance collected. These data will then be utilised in a detailed analysis of the biostratigraphy, palaeoecology, palaeoenvironments and palaeogeography of the deposits. The count data will then be analysed using the statistical package PAST, and will be presented using STRATABUGS.

Further hydrocarbon exploration and development are a priority to ensure energy security. Development of a robust biostratigraphic model for the EGoM basin will greatly facilitate future exploration and development activities in this basin.

Keywords: Dinoflagellate, Jurassic, Cretaceous, Gulf of Mexico, Biostratigraphy